DESIGN OF A HYDRO-ELECTRIC POWER PLANT ON THE WHITE SALMON RIVER, WASHINGTON

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1912

UNIVERSITY OF ILLINOIS

May 29, 1912

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

TADASHI IIDA

ENTITLED DESIGN OF A HYDRO-ELECTRIC POWER PLANT ON THE WHITE SALMON RIVER, WASHINGTON

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

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Introduction.

The electric industry has made tremendous progress in the twenty odd years since it was born--- progress much more rapid than that made by the steam engine a century ago.

The development of water power is an economic necessity. The stock of coal is being rapidly depleted and the cost of steam power is increasing accordingly. Industrial growth, as a consequence, will cease if cheap power is not available. A few years ago the use of water power was limited to the immediate locality where it was developed, but it is becoming recognized that with properly organized companies and with plants suitably planned the benefits of hydro-electric power may be supplied at reasonable cost even in sparsely settled regions. Now an electric plant can serve the industrial needs of an area within a radious of 200 miles or more since the development of high tension power transmission.

The factors that govern power development are three:-

1 The volume of water available,

2 The fall through which this water can be utilized

3 The market for the power when developed.

A study these factors are necessary, in order to ascertain whether the proposition will be a paying one.

PART 1

The Market.

The requirements of power consumers are by no means uniform. They vary from hour to hour, from day to day, and from season to season . This requires that a certain reserve be maintained at all times to meet "Peak loads" during the day and for regular and extraordinary demands that arise from time to time. There are, however, several ways by which the possible amount of consumption of electrical power may be obtained.

Electrical power finds its market in the following fields:

I Lighting service,

2 Industrial service,

3 Traction .

Analysis of the power market.

The following information concerning power requirements in the prospective towns, and villages has been obtained:

In order to determine a growth of population in the territory and also to design the power plant large enough to meet for this growth, a graph is plotted as shown in plate no. 1. The ordinate is the population, and the U.S. census year the abscissa. By means of this graph the growth of each town and consequently (assuming the power consumption is proportional to the increase of population) the power consumption in 1930 is determined.

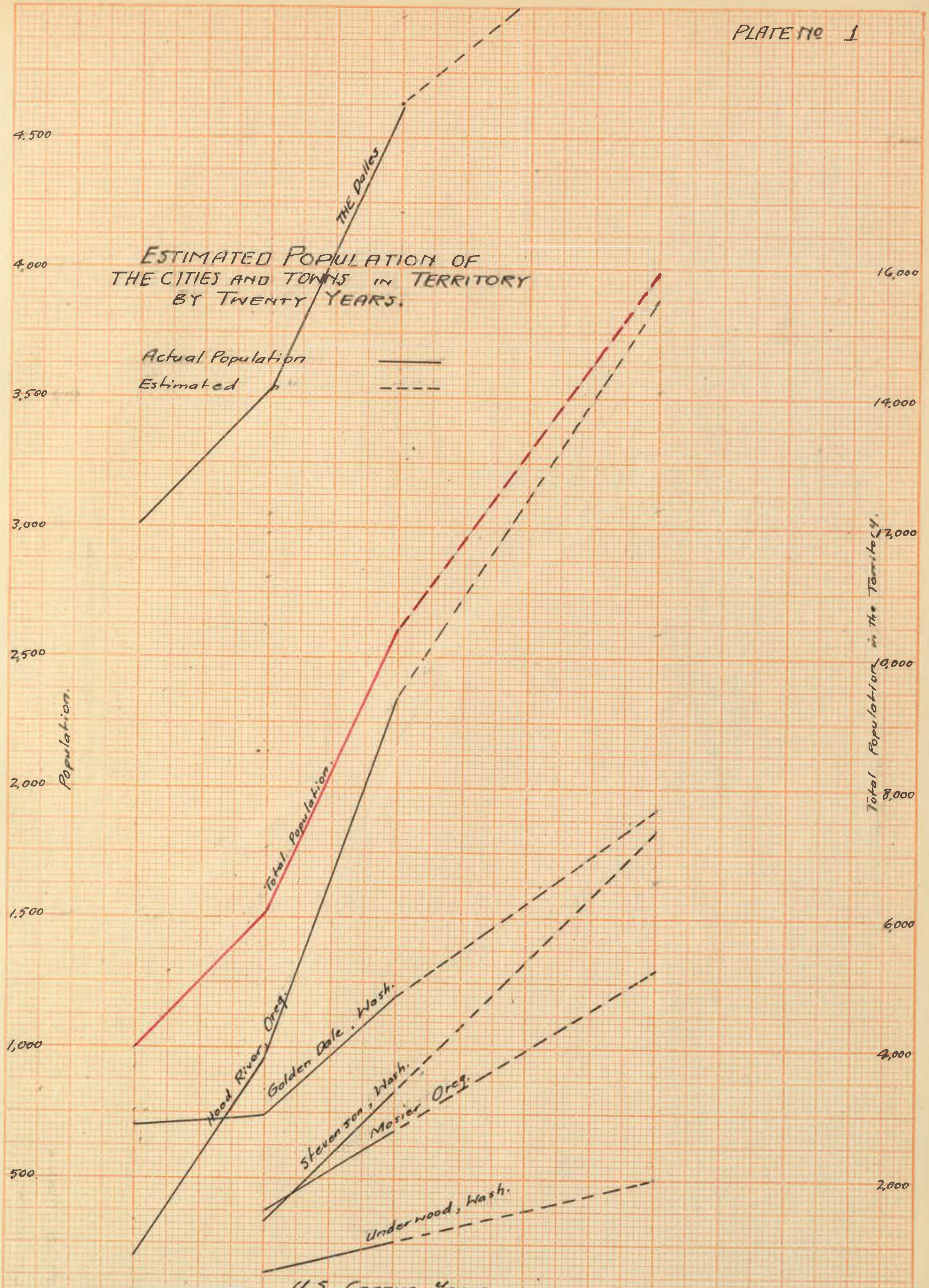


PLATE No 1
ESTIMATED POPULATION OF THE CITIES AND TOWNS IN TERRITORY BY TWENTY YEARS.
Actual Population
Estimated
THE Dalles
Total Population.
Hood River, Oreg.
Golden Dale. Wash.
Stevenson, Wash.
Mosier, Oreg.
Underwood, Wash.
Population.
Total Population in the Territory.
U.S. Census Years.
1890
1900
1910
1920
1930.
500.
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4.500
2,000
4,000
6000
8,000
10,000
12,000
14,000
16,000

Power Users Tabulated

Name of Town. The-Dalles City, Oreg.

Population 4,880 (1910).
6.600 (1930). Estimated.

Rail Road Oregon R.R.

Numbers of Bank 4.

Number of News paper 3.

No	Concern	Hour	Hors-Powers	Operates Hours	Load Factor
1	News Paper Printing.	8-6 PM	8	10	·7
2	" "	8-6 PM	5	10	·7
3	Flour Mill.	6-12	150	18	·8
4	Saw Mill	7-5	100	10	·8
5	Woolen Mill	7-5	75	10	·7
6	Laundry.	6-6	5	12	·8
7	Canning factory	8-6	20	10	·8
8	Sash & door factory.	8-6	150	10	·8
9	Cultery factory.	6-6	70	12	·8
10	Boots and Sheos Maker	8-6	5	10	·6
11	Laundry.	6-4	3	10	·8
12	Packer	7-5	20	10	·7
13	Grain elevator	8-6	15	10	75

Total Horse Power Used for Industrial Service 626 H.P.

Total Horse Power used for lighting Service. 380 H.P.
" " " " " street Lighting " 15 H.P.

Estimated Power Consumption in 1930.

Total Horse power to be used for Industrial Service 870 H.P.
" " " " " " " Lighting " 530 H.P.
" " " " " " street Lighting 25 H.P.

Name of Town. Goldendale, Wash
Population 1,203 (1910)
1,940 (1930) Estimated
Rail Road Great Northern R.R. (Branch Line).
Number of Banks 3
Number of News papers 2

No	Concern.	Hour	Horse Power	Hours Operats	Load Factor
1	Flour Mill	6-6 PM	40	12	·8
2	" "	6-6	70	12	·8
3	Saw Mill	8-6	150	10	·8
4	Planing Mill.	7-5	80	10	·7
5	News paper	8-6 AM	6	10	·7
6	Laundry	6-4 PM	3	10	·8
7	Grain Elevator	7-5	20	10	·6
8	Single Mill	6-6	50	12	·8
9	Saw Mill	8-6	75	10	·8

Total Power used for Industrial Service 494 H.P.

Total Horse Power used for Lighting Service 96 H.P.

Estimated Power Consumption in 1930.
Total Horse Power to be used for Industrial Service 700 H.P.
" " " " " " Lighting " 155 H.P.

Name of Town. Underwood, Wash.
Population 258 (1910)
500 (1930) Estimated.
Rail Road. Great Northern R.R.

Estimated Power Consumption in 1930
Total Horse Power to be used for Lighting Service 40. H.P.

Name of Town.	State	Population 1910	Estimated Power Req. in 1930. HP.
Bingen	Wash.	211	20
Husum	"	395	40
Hart Land.	"	163	15
Center ville	"	548	50
White Salmon.	"		30
Lyle	"		10
War nick	"		10.

Name of Town — Hood River, Oreg.

Population. — 2,932 (1910)
3800 (1930.) Estimated.

Rail Road. Oregon R.R.

Number of Banks 2

Number of News Papers 2

No	Concern.	Hour	Horse Power	Hours Operat's	Load Factor
1	Carriage factory.	8-6 PM	20	10	·8
2	Furniture Factory.	6-6	50	12	·8
3	Dairy.	2-12	5	10	·7
4	Laundry.	6-6	5	12	·7
5	News Paper.	6-6 AM	6	10	·8
6	Printing.	8-6	5	10	·6
7	Boots and Sheos Factory.	8-6	25	12	·8
8	Packing Co.	6-12	20	18	·8
9	cultury	8-6	30	10	·8
10	Foundry.	8-6	5	10	·7
Total Horse Power used for Industrial Service			171 HP		
11	Lighting		230 HP		
12	Street Lighting.		9 HP		

Estimated Power Consumption in 1930

Intustrial power to be used. — 250 H.P.

Total H.P. for Lighting service. — 310 H.P.

Name of Town. — Mosier, Oreg.

Population. — 684 (1910)
1,240 (1930) Estimated.

Estimated Power consumption in 1930

Total Horse Power to be used for Industrial Service — 70

" " " " " " Lighting " — 100 H.P.

Name of Town. — Stevenson, Wash.

Population. — 833. (1910)
1,770 (1930) Estimated

Estimated Power consumption in 1930

Total Power to be used for Industrial Service — 60 H.P.

" " " " " " Lighting " — 110 H.P.

Load curve.

From the information in above invention of power market a load curve at switch board is plotted- (Plate 2). Although the load curve itself will vary from day to day as the various demands for power vary, yet the characteristic of the load curve, due to certain demands, can be quite safely predicted.

It is manifest that no plant will receive its maximum returns without operating at full load all of the time. On every plant the fixed charges, which include interest on first cost, depreciation charges, and taxes, continue at a uniform rate every hour of the day and every day of the year. It will be noted at once that if a machine can be operated at its full capacity for the entire time, that the work done under the most economical conditions as far as each unit of output is concerned.

Load factor.

The ratio of the average to the maximum load is called "load factor" .

In order to have a plant work at the maximum advantage, it must be designed to fit the contingencies of the load. The operation of a machine at partial load is not only expensive on the basis of fixed charges, but is still more so on account of the decreased efficiency under such conditions.

From the load curve, we have for the load factor:

$$\text{Load Factor} = \frac{\text{Average Load.}}{\text{Max. Output Load.}}$$

$$\text{Winter Load Factor} = \frac{1205}{2{,}000} = 60.25\ \%$$

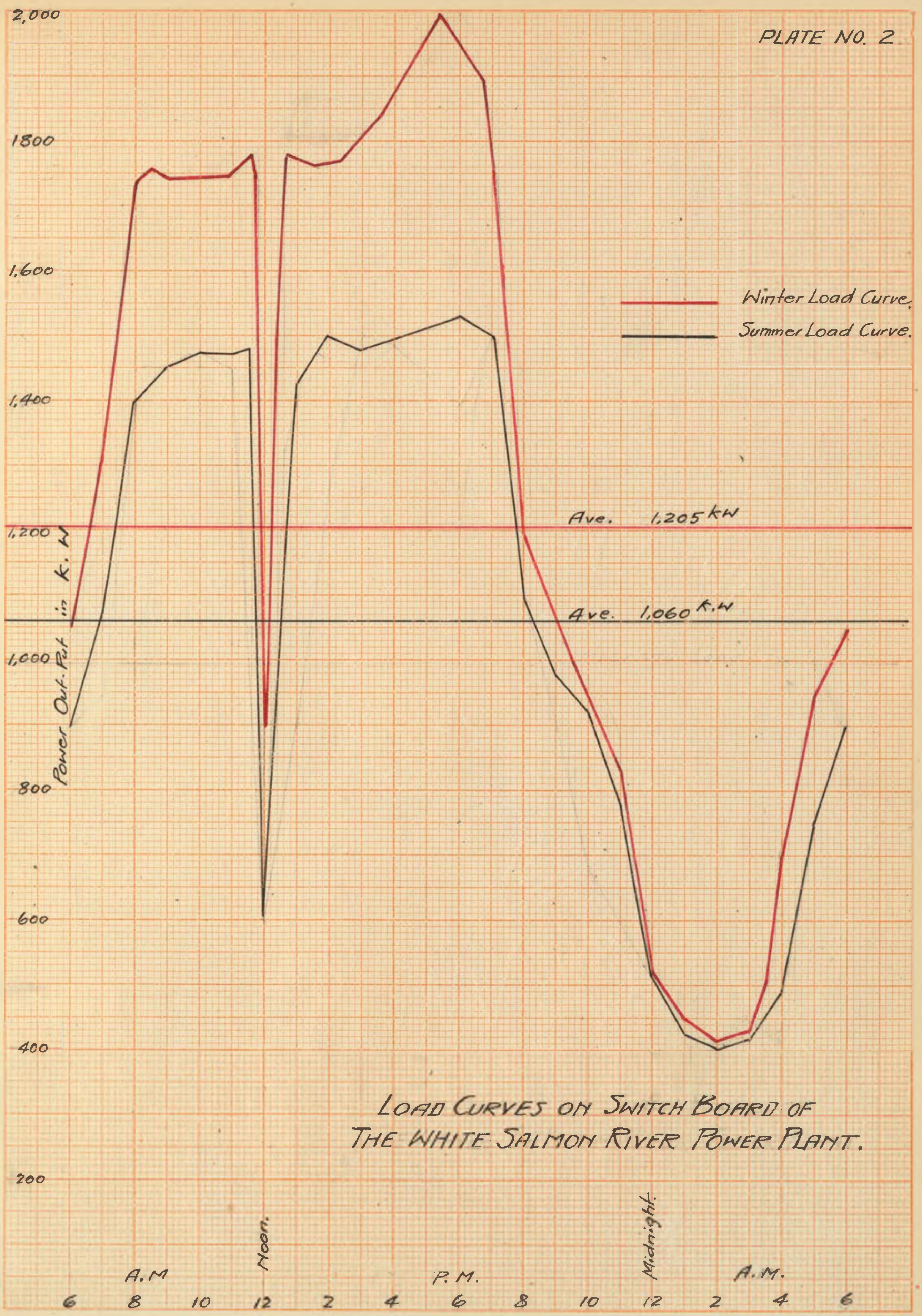
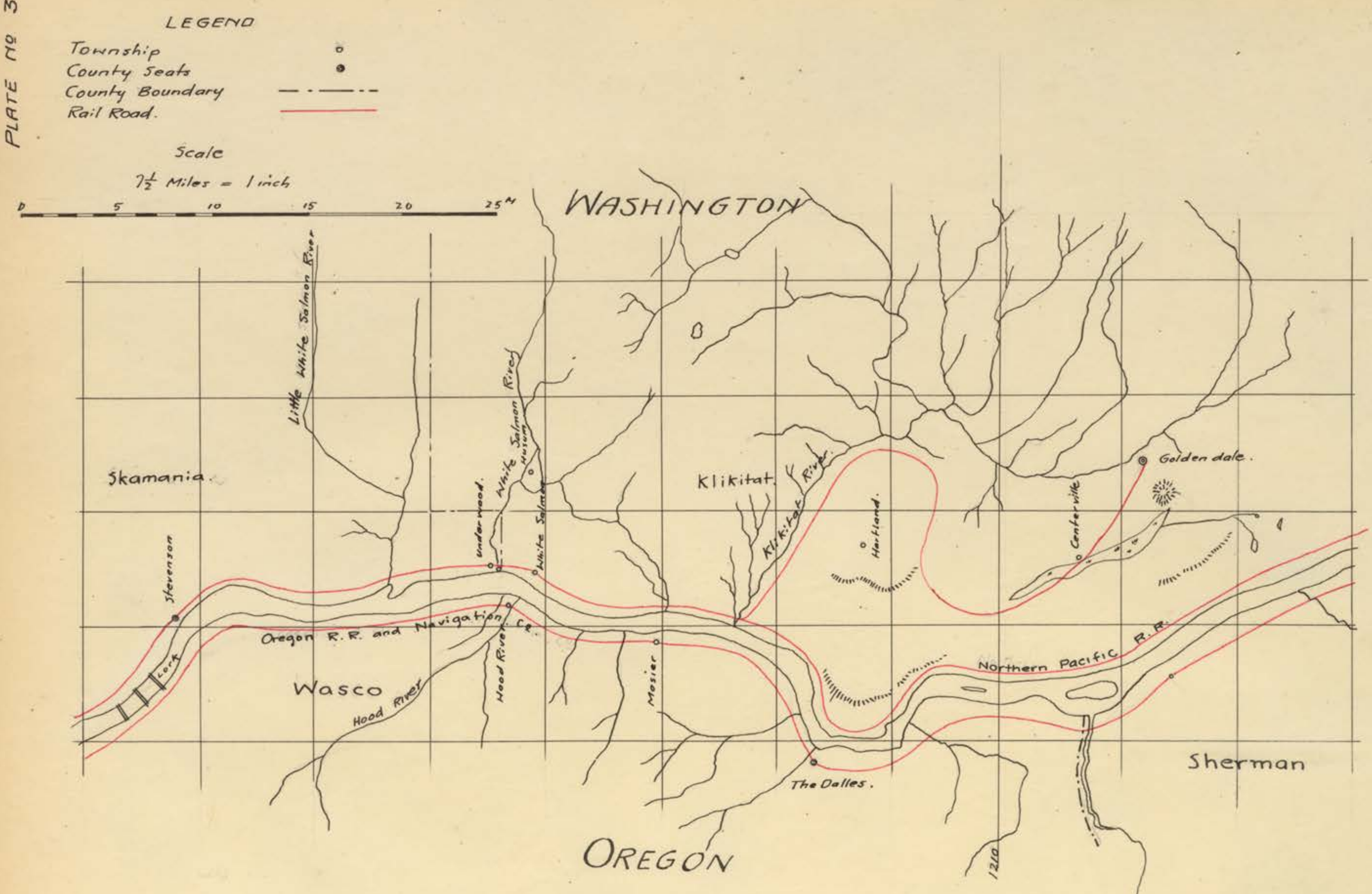


PLATE NO. 2
Winter Load Curve.
Summer Load Curve.
Ave. 1,205 kW
Ave. 1,060 K.W
Power Out-Put in K.W
2,000
1800
1,600
1,400
1,200
1,000
800
600
400
200
Noon.
Midnight.
A.M
P.M.
A.M.
6
8
10
12
2
4
6
8
10
12
2
4
6
LOAD CURVES ON SWITCH BOARD OF
THE WHITE SALMON RIVER POWER PLANT.

Summer Load Factor $= \frac{1,060}{1,530} = 72.5\ \%$

PLATE No 3.



MAP OF TERRITORY OF THE WHITE SALMON RIVER POWER PROJECT.

Bibliography.

Water Power Engineering . D. W. Mead. Mc Grow & Hill 1908

Hydro-Electric Practice . Von. Schon. Lippincott Co. 1908

U. S. Census of Population. Dept. of Interior

Report of Industry of Washington. " " "

" " " " Oregon. " " " "

PART 2.

Water Power Development.

The investigation of markets and the consequent estimated load curve shows that for this project a water power to produce electrical energy of 2,000 K.W. is required. With this figure in mind, the flow of stream of the White Salmon River is investigated.

Flow of stream.

General consideration: All streams derive their supply ultimately from the rainfall, and in general, the amount of the run-off is equal to the rainfall less the evaporation. It follows, therefore that variation in rainfall from year to year is reflected in a general way by variation in stream flow; but local conditions-temperature, topography, vegetation, forest, and soil- govern the exact relation between rainfall and stream flow to such an extent that only the more prominent fluctuations of rainfall are apparent in the runoff.

It is a common practice among engineers, when gagings are not to be had, or where they are very limited, to make estimates of stream discharge from precipitation data , or, from comparison with other streams whose flows are known, taking into account as far as may be the differences in the rainfall, the climate, and the other various characteristics of the different water-sheds.

Determination of Discharge of the WHITE SALMON RIVER.

In determining the discharge of the White Salmon River the plan outlined above has been followed, except that the record of only the summer flow for 1909 was available instead of the record of a series of years.

The streams compared are Columbia River and Willamette River. In this region all rain comes from the Pacific Ocean and the characteristics of the water-shed, especially that of the latter stream are very similar to those of the River under consideration the former being the trunk river of the White Salmon . It is worth while to describe the water-sheds before going into the main discussion.

Columbia River Drainage Basin.

The Columbia River has its source in Columbia Lake, in the eastern division of the Kootenai district, in British Columbia. The total drainage area of the Columbia is estimated to be 259,000 square miles, divided as follows:

Area of Columbia River Drainage Basin.

	Square Miles.
Oregon	55,370
Washington	48,000
Idaho	81,380
Montana	25,000
Nevada	5,280
Wyoming	5,270
British Columbia	38,700

This area is limited on the east by the Rocky Mountains and is traversed north and south by the Cascade and Coast ranges. Between the mountain ranges are rolling, rough, and mountainous table lands.

Principal Tributaries of Columbia River.

From the west and north	From the east and south.
Kettle River.	Kootenai River.

Sanpoil River.

Okanogan River.

Methow River.

Chelan River.

Entiat River.

Wenatchee River.

Yakima River.

Klickitat River.

White Salmon River.

Lewis River.

Kalama River.

Cowlitz River.

Clark Fork.

Colville River.

Spokane River.

Snake River.

Walla Walla River.

Umatilla River.

Willow River.

John Day River.

Deschutes River.

Hood River.

Willamette River.

Clatskanie River.

The area drained by the Columbia includes perhaps the largest consolidated area of forests in the world.

The rainfall is distributed over the area most irregulary. From the Pacific coast eastward to the summit of the Coast Range the mean annual rainfall varies from 100 to 150 inches. In the basins between the Coast and Cascade range, it drops to about 40 inches per annum. It increases again to about 100 inches on the summit of the Cascade Range, and decreases very rapidly beyond the summit, until at the eastern base of the Cascade it has dropped to about 14 inches. At the mouth of Snake River the mean annual rainfall is about 9 inches. Beyond this point the rainfall again increases in Washington and northern Idaho to about 20 inches, while in eastern Oregon it continues at about 9 inches or less. In the eastern areas a large proportion of precipitation appears as snow, and during the winter months the streams are more or less icebound. West of the Cascade Range, however, the winter stream flow is not affected by ice.

The highest recorded flood in the Columbia occured in June, 1894. The highest floods on the tributaries are invariably caused by the "chinook"--a warm wind, usually accompanied by rain, occuring in the spring and fall. The fall "chinook" usually during highest waters, as it may occur immediately after a heavy snow has covered the mountain ranges. The Columbia itself is not greatly affected at such times.

Willamette River Drainage Basin.

The Willamette River drains a trough shaped area, extending north and south between theCoast and Cascade ranges in Oregon. The area is roughly rectangular, approximately 230 miles in length and about 85 miles in width.

From the summit of the mountain ranges the slopes are steep, but they merge gradually into a wide alluvial valley or into gently, rolling agricultural lands.

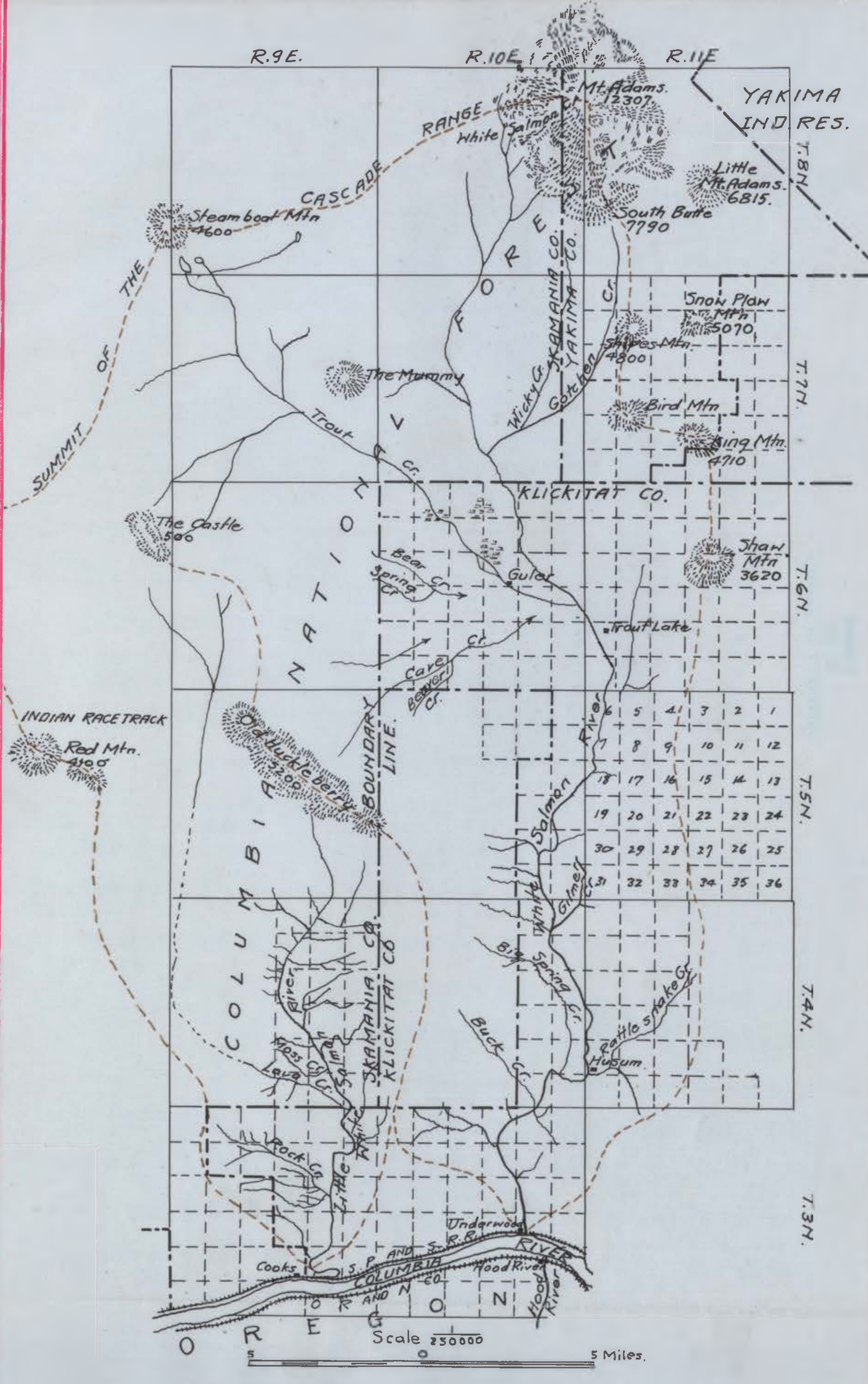
The entire drainage area of this river was originally primeval forest, and although considerable areas in the valley have been cleared for agriculture the area may still be considered densely forested. The portions of the basin that contribute most to the flow of the streams are almost entirely within the boundaries of the national forests, while the privately owned timber lands extend from the boundaries of the national forests to the main stream in the valley, except where lands have been cleared . Thus whatever beneficial influence the original forest may have exerted on the regulation of stream flow, its effect is still in evidence, as the water producing portions of the area have not been disturbed. The mean annual rainfall presents some rather peculiar features. Although precipitation records at the summit of the Coast Range are meager, it is likely that the total annual rainfall is as much as 150 inches. As the eastern slope of the Coast Range is descended, precipitation falls very rapidly to about 40 inches, but gradually increases again until at the summit of the Cascade Range it is approximately 100 inches annually. At the mouth of the river the precipitation is approximately 50 inches, which gradually decreases to about 40 inches in the vicinity of Corvallis. On the mountain ranges part of the precipitation is snowfall, and the country is subject during the spring and fall to the warm chinook wind, accompanied by rather sudden melting of these snows, which frequently causes considerable damage from floods.

The highest known flood in the Willamette Valley occured December 1861. The highest gage reading at Portland since that date occurred in 1894, but was due to back water from Columbia River.

White Salmon River Drainage Basin.

The White Salmon River has its source in three glaciers on the west side of Mount Adams. The largest of these is White Salmon Glacier and to the south Avalanche Glacier, and to the north of this lies Pinnacle Glacier. The river flows southward and empties its waters into Columbia River at the town of Underwood. The source and mouth of the river lie on the same meridian. The river has a total length of 38.5 miles and a total drainage area of 352 square miles. The plate no. 4

PLATE NO. 4.



MAP OF DRAINAGE BASIN OF WHITE SALMON RIVER, WASHINGTON.

is a map of this drainage area .

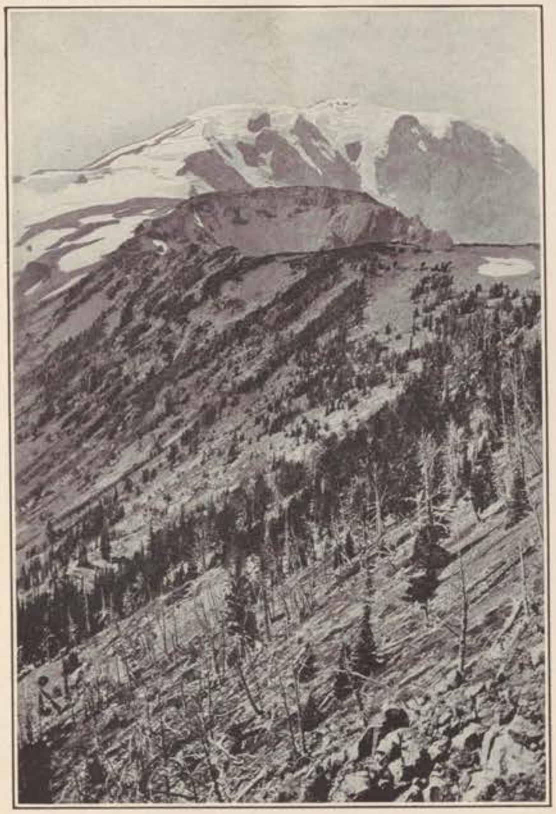
Trout Creek is the principal tributary. It drains the high spurs and secondary peaks to the southwest of Mount Adams, flows in a south-easterly direction, and empties into the White Salmon near Trout Lake post office. Three small creeks-- Big Spring Creek from the west and Gilmer and Rattlesnake creeks from the east --- empty into river below Trout Creek in the vicinity of Husum. Gotchen Creek, the principal tributary above Trout Creek, drains the high spurs to the southeast of Mount Adams.

The drainage area of the White Salmon River is distributed as follows:-

	Square Miles.
Above the mouth of Trout Creek-------	84
Below the mouth of Gilmer Creek------	290
At Husum----------------------------	300
At Underwood------------------------	352
Trout Creek-------------------------	85

The prominent topographic feature of the area is Mount Adams (Plate No. 5.) and the spurs and secondary peaks that surround it. These peaks crown the boundary lines of the drainage area, which is roughly V-shaped with Mount Adams at the apex. On the west Steamboat Mountain (at an elevation of 4,600 ft.), the Castle (5,100 ft.), and Old Huckleberry (5,200 ft.) stand like sentinels on the summit of the divide. South Butte (7,790 ft.), Snow Plow (5,700 ft.), Snipes Mountain (4,800 ft.), King Mountain (4,710 ft.) , and Snow Mountain (3,620 ft.) prominently mark the eastern boundary. The basin is therefore roughly trough shaped with several

PLATE NO. 5.

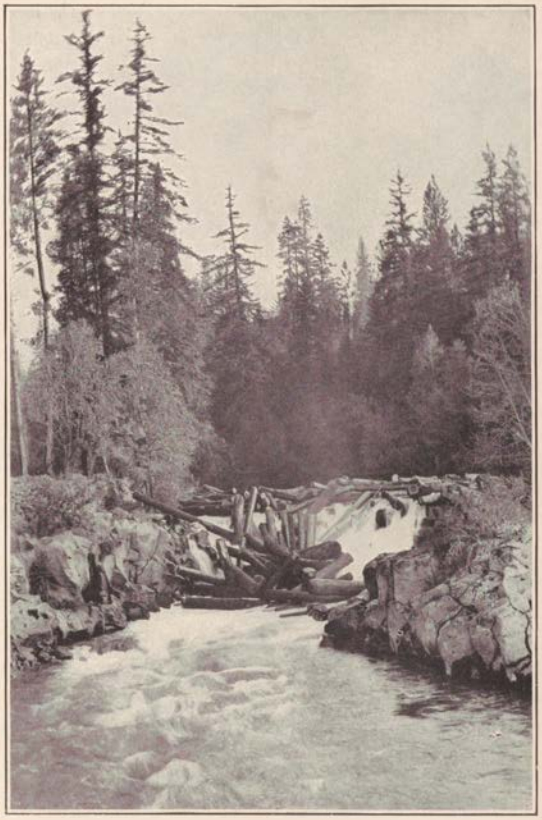


A. MOUNT ADAMS FROM THE SOUTHEAST.

Smaller peaks within it. The topography is bold and picturesque. The streams flow in deep canyons on beds of bowlders, with here and there ledges of basalt or stretches of box canyons that have vertical jagged sides and solid beds.

The whole drainage basin is covered with lava and basalt, in which the canyons have been carved. Near Mount Adams many cinder cones and bombs give evidence of recent volcanic activity. Red Butte, 3 miles northeast of Mount Adams, has an elevation of 7,203 feet. The cone is 500 feet high, with a crater I75 feet in diameter and 75 feet deep. Much of the pumice, scoria, and lava from these cones is highly colored, and volcanic glass is found in various shades from black masses to transparent globules. The bombs on the lower slopes of Mount Adams are rough spherical masses of lava, of homogeneous texture, Near the headwaters are large areas of partly exposed lava beds. A line of caves may be traced along this formation for 20 miles or more. In some places the caves have been formed by the Liquid mass flowing from under a solidified crust; in others they may have resulted from the action of gases and are in effect huge bubbles. One of these in Sec. 25, T. 6N., R. 9 E. is widely known as the Ice Cave. The temperature is so low that water accumulating and freezing during winter does not thaw out during the following summer. The ice is found in masses on the floor and dips through crevices in the roof. These form during the winter and are partly melted during the summer. The area in which these caves lie is drained by small intermittent water courses in which the water sinks at many points. It is likely that much of the surface water finds its way deep into these lava beds, emerging into lower

PLATE NO. 6.



B. LOG DRIVING ON WHITE SALMON RIVER NEAR HUSUM GAGING STATION.

portions of the White Salmon River.

The main river flows in a deep canyon whose sides are bordered by heavily rolling table-lands or mountains. From a point 3 miles below Trout Creek to a point 2.5 miles above Husum the river flows in a narrow box canyon. This has been cut squarely into the basalts and the recent lava flows that have overspread them. The canyon is about 11 miles long and nearly every part of it would afford a favorable site for a dam. Trout Creek, on the other hand, is essentially a surface stream below Trout Lake. The banks are bordered by fairly level stretches of open meadows, and agricultural land.

The north line of T. 6N. forms the southern boundary of the Columbia National Forest. Logging operations have been carried on for years in this drainage area, for the most part on lands adjacent to the river (Plate No. 6). The entire drainage area is heavily forested except where cleared for agriculture. Within the national forest the timbered area constitutes 73 percent of the total , 26 percent is burned, and I percent is above timber line. The timber is red or yellow fir and yellow pine. The stand of timber within the national forest is about as follows :-

	Percent.
0 to 2,000 feet b.m.per acre----------------	I8
2,000 to 5,000 feet b. m. per acre----------	30
5,000 to I0,000 " " " " -------------	40
I0,000 to 25,000 " " " "--------------	8
25,000 to 50,000 " " " "--------------	4

There are no railroads in the drainage area except the Spokane, Portland and Seattle Railway which crosses the river at its mouth in its course along the right bank of Columbia River. The principal towns are Underwood and White Salmon (Plate No. 3), the latter being on the high table-land east of the river near the mouth . Husum post office is near the mouth of Trout Creek, on the east side of the river , and Guler is on Trout Creek near the outlet of Trout Creek. Good wagon roads and stage lines connect all the towns. The upper portion of this area is a favorite summer resort, and many campers will be found around Trout Lake and Guler in the summer.

The rolling benches along the lower part of the river have been cleared for agriculture . Most of these lands are in orchards and the territory has become justly famous for the excellent quality of its apples and other fruits. In T. 6N. the lands along the river are comparatively flat and some of them were natural meadows. These open lands, have been en larged by clearing the timber around them and the whole valley presents a delightful picture of prosperity. In this portion of the valley irrigation is practiced extensively. The water for the ditches is diverted from Trout Creek and the White Salmon River. These ditches are small but numerous and they furnish an abundant supply of water.

So far as known, the basin affords no large reservoir sites. Trout Lake is the only flat area that would be suitable, but the outlet is a broad valley and no favorable dam sites are found. Most of the water runs off during the spring, exposing the lake bed as a marshy flat. A small amount of storage might be developed at steamboat Lake near the headwaters of Trout Creek.

Owing to the porous lava rocks of which the area is composed and the soil resulting from its disintegration, a large amount of water is held in ground storage. Springs are numerous along the river and seepage into it is large. Most of the summer flow, however, is supplied by glaciers on Mount Adams. Above Trout Creek, White Salmon River has its lowest discharge during cold weather , while on hot summer days the discharge is high and the water is heavily loaded with glacial silt. Trout Creek, on the other hand, has its lowest period at the end of the summer season. During the winter months the discharge is relatively high from surface drainage from the large area through which it flows. The two streams, therefore, maintain a well balanced flow during the year. Floods occur during heavy rains when accompanied by chinook winds, which suddenly melt the snow on the hills. The heaviest floods are likely to occur in autumn after an early snowfall. A flood from this cause of greater or less magnitude may be expected about the middle of each November and at other times during the winter months. Spring floods occur periodically , but are rarely so severe as the fall flood and are not so sudden. These result from the more gradual melting of snow in the mountains as warm weather approaches. This melting is arrested at night , with the result that the stream shows daily variations of considerable magnitude.

No discharge data are available except those obtained during the summer of 1909. (Plate No. 7)

Daily Gage Height, in feet and Discharge, in Cub.-ft per Sec. of WHITE SALMON RIVER at Husum, Wash, for 1909.

Month. / Day.	Sept		Oct.		Nov.		Dec.	
	Gage Hight	Disch.	Gage Hight.	Disch.	Gage Hight	Disch.	Gage Hight	Disch.
1			2.86	510	3.12	672	5.85	
2			3.00	585	4.15	1290	5.10	
3			3.00	585	5.90		4.80	1700
4			3.10	640	6.20		4.65	
5			3.10	640	4.25	1350	4.45	
6			2.90	535	3.80	1070	4.33	1380
7			2.90	535	3.50	885	4.20	1330
8			3.00	585	3.52	890	4.12	1270
9			2.95	560	3.70	1,010	4.01	1200
10			3.05	612	3.60	950	3.98	1120
11			3.08	629	3.45	855	3.96	1100
12			3.00	585	3.30	750	4.16	1280
13			2.90	535	3.21	705	4.60	1570
14			2.90	535	3.20	700	4.45	1420
15			2.95	560	3.18	684	4.20	1320
16			3.03	602	3.15	670	4.12	1270
17			3.00	585	3.14	660	4.10	1250
18			3.00	585	3.95	1170	4.06	1235
19			3.00	585	6.35		4.03	1220
20			3.05	612	6.80		4.02	1215
21			3.10	640	4.90	1760	4.00	1200
22			3.00	585	5.25	1,970	3.90	1150
23			3.05	612	7.30		3.90	1150
24	3.10	640	3.08	629	7.65		3.90	1150
25	3.10	640	3.06	618	5.90		3.88	1140
26	3.06	618	3.00	585	5.20	1960	3.85	1100
27	3.00	585	2.92	545	4.80	1700	3.83	1095
28	3.10	640	2.96	565	4.75	1670	3.80	1090
29	3.05	612	3.12	651	5.25	1970	3.75	1070
30	3.25	722	3.10	640	7.30		3.85	1100
31			3.18	684			3.85	1100

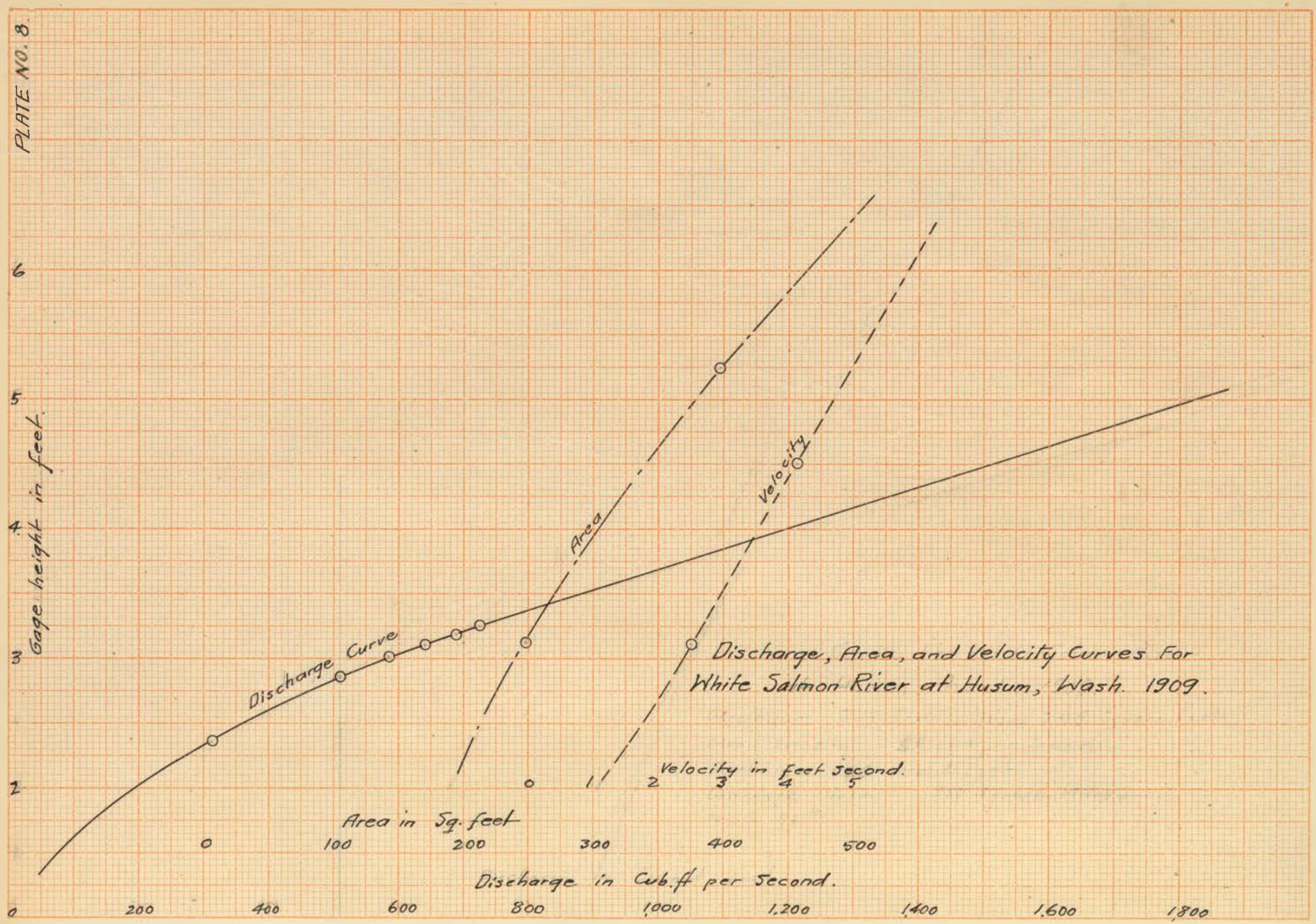


PLATE NO. 8
Discharge, Area, and Velocity Curves For
White Salmon River at Husum, Wash. 1909.
Gage height in feet.
Discharge Curve
Area
Velocity
Velocity in feet second.
0 1 2 3 4 5
Area in Sq. feet
0 100 200 300 400 500
Discharge in Cub. ft per Second.
0 200 400 600 800 1,000 1,200 1,400 1,600 1,800
2 3 4 5 6

PLATE NO. 9.

IRRIGATION DITCHES IN WHITE SALMON RIVER DRAINAGE BASIN.

Diverting Water From White Salmon River.

Name of Ditch	Location of head-gate	Bank of Stream.	Approx. Capacity Cu.ft./Sec.
Wagnitz	N.E. ¼ Sec. 3, T. 6, R.10	Right	3
Thomas	NW. ¼ Sec. 14, T. 6, R.10	do	2
Coats and Duncan	do	Left	10
Dutch	NE ¼ Sec. 31, T. 6 R.10	do	5
Pearson	do	do	5
Huber	SE. ¼ Sec 24, T. 6, R.10	Right	3
Coats and Bro.	SE. ¼ Sec. 14, T. 6 R.10	Left	5
Trout Lake	N.E. ¼ Sec. 31, T. 6, R.11	do	25

Diverting Water From Trout Creek.

Mc Donald	N.E. ¼ Sec. 22, T. 6, R10	Right	8
Pearson-Thompson	do	do	7

Conclusion of the discharge of the White Salmon River.

By combining the rainfall data at Portland and Fort Vancouver a 57 year record of rainfall has been obtained. A record of 30 years is available at Cascade Locks, one of 25 years at Hood River, and one of 46 years at The Dalles. These are the only stations of value in the vicinity of the region under consideration.

The mean annual rainfall for the climatic year at Portland is 42.3 inches, for Cascade Locks 77.9inches, for Hood River 35.9 inches, and for The Dalles I6.8 inches. The rainfall for each year for each station represented in percentages has been averaged. The result is called the percent rainfall for Columbia River Gap.

Rainfall and other climatic phenomena undoubtedly recur in cycles. In the present case the percent rainfall curve for Columbia River Gap has been smoothed by the formula:

$$R' = \frac{1}{10}(a + 2b + 4c + 2d + e),$$

Where c = The rainfall for any one year.

b = The " " the preceding year.

a = The " " the next preceding year

d = The " " the following

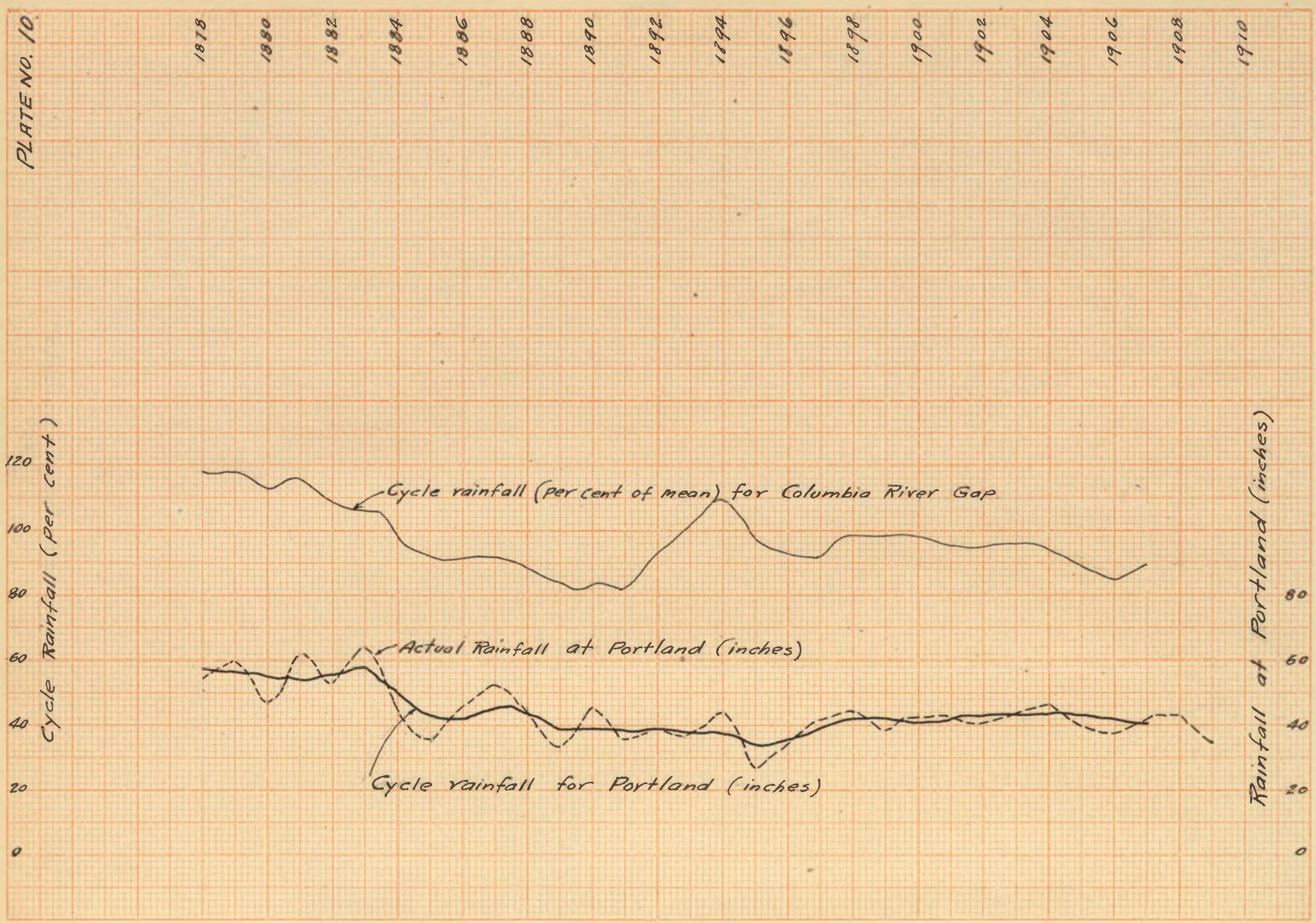
e = The " " the next following

R'= Cycle value for the year c.

This curve is shown in plate no. 10. for both the percent rainfall for Columbia River Gap, and Portland record in inches. The actual record, by years, for Portland is also shown by a dotted line.

The next question is to determine how closely river

PLATE NO. 10



1878
1880
1882
1884
1886
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908
1910
Cycle Rainfall (per cent)
120
100
80
60
40
20
0
Cycle rainfall (per cent of mean) for Columbia River Gap
Actual Rainfall at Portland (inches)
Cycle rainfall for Portland (inches)
Rainfall at Portland (inches)
80
60
40
20
0


PLATE NO. 11.
1878
1880
1882
1884
1886
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908
1910
Rain-fall (inches) Columbia River Gap.
140
120
100
80
60
Rain fall (percent of mean)
Relation of Rainfall to Discharge, Columbia and Willamette Rivers.
Run-off (inches) Willamette River
60
52
44
36
28
Run-off, Willamette River
Run-off (inches) Columbia River
16
14
12
10
8
Run-off, Columbia River

discharge may be expected to follow variation in rainfall. Two features will be considered:-

I The annual yield of a drainage area.

2 The minimum flow.

The annual discharge for the Columbia and the Willamette rivers has been reduced to equivalent inches of rainfall over their respective drainage area. The results are plotted in plate no. 11. On the same diagram is shown the percent rainfall for Columbia River Gap, as explained on page I9, and the climatic year has been used.

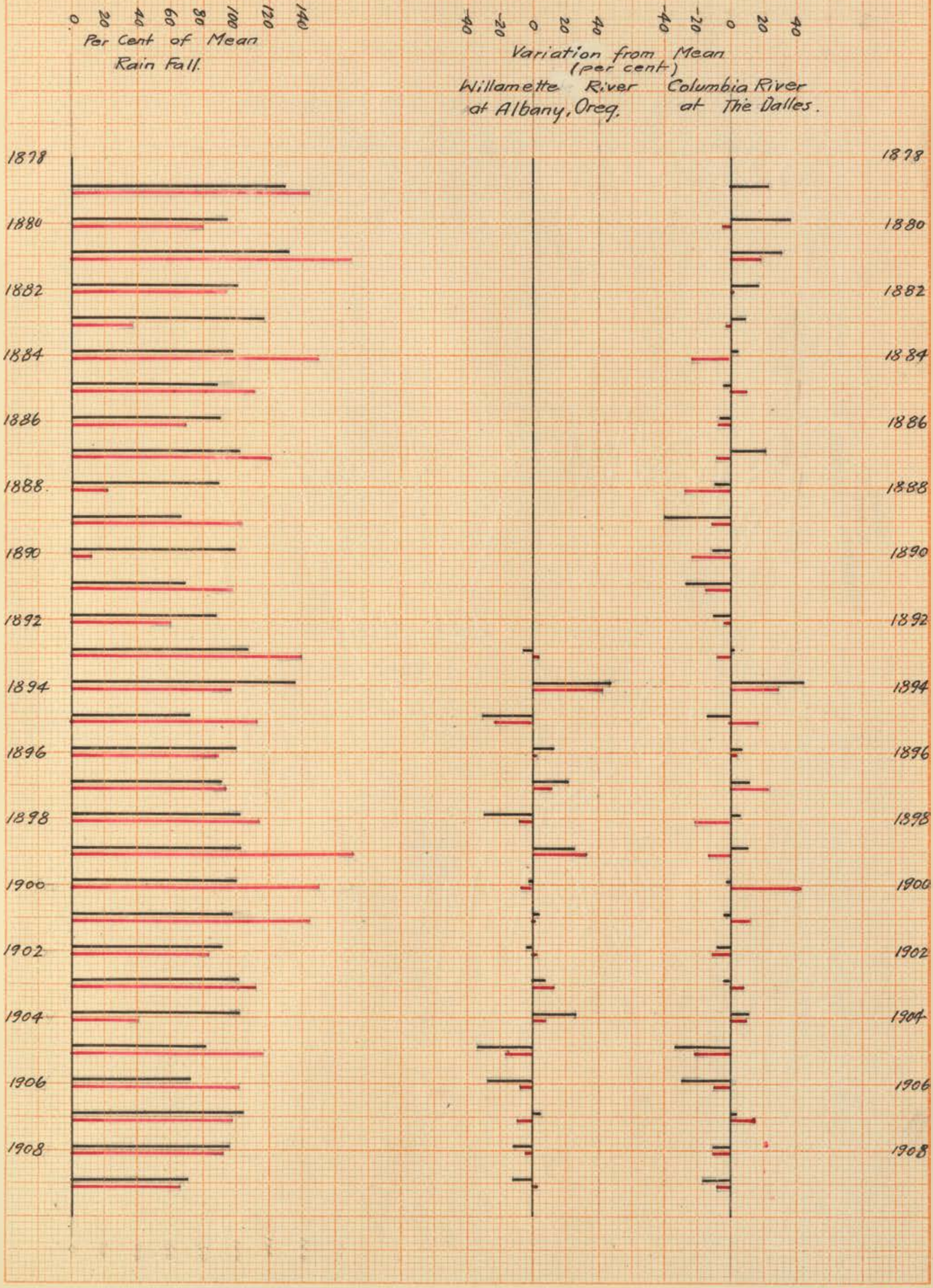
The general parallelism of the rainfall and runoff curves is very striking particularly in those of the Columbia River.

Annual Yield and Minimum Flow.

In order to bring out the relative variation between the annual yield and the minimum rate of flow, plate no. 12 has been prepared. In this plate the black bars represent the percentage variation for each year of the mean annual flow, from the average of the years comprising the record. The climatic year has been used. The red bars represent in the same manner the percentage variation of the mean discharge for the lowest week from the average of all years comprising the record. The preceding tables must be consulted for actual values, for only the relative yearly variation are depicted in the diagram.

At the bottom of the diagram are shown the annual variations in rainfall for the stations at Portland, CascadeLocks, Hood River, and The Dalles. The rainfall for each year at each station is first expressed in percentage of the mean annual rainfall for that station. These percentages are

PLATE NO. 12.


0 20 40 60 80 100 120 140
Per Cent of Mean Rain Fall.
-40 -20 0 20 40
-40 -20 0 20 40
Variation from Mean (per cent)
Willamette River at Albany, Oreg.
Columbia River at The Dalles.
1878
1880
1882
1884
1886
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908

then averaged for the several stations. These are shown as black bars. In the same manner the percentage variation of rainfall during the month of August and September for each year at Portland, Cascade Locks, Hood River, and The Dalles stations is shown by the red bars. The amount the bars exceed or fall short of IOO percent indicates the variation from the normal.

The year I905 was a very dry year and was followed by another one in which the precipitation was even less, but the stream discharge did not fall quite so low. The year I909 also was a very dry year, almost on a parallel with I905. Segregating the results for these three dry years, we find the following variation :-

Variation in Percentage of Annual Discharge and Rainfall from the Average.

TABLE NO. 1.

Name of River

Discharge:	Length of Record (years)	1905	1906	1909
Columbia River	31	-38	-32	-17
Willamette River	18	-39	-27	-14
Deschutes River	5			- 8
John Day River	5	- 20	+ 9	-25
Umatilla River	9	-54		-25
Naches River	5	- 9	- 5	-37
Tieton River	7	-17	-31	-18
Methow River	6	+ 7	-15	-14
Spokane River	12	-50	-33	
Clark Fork	6	-41	-35	+10
Ceder River	10	-25	-21	-16
Precipitation	57	-18	-27	-31.

From the table of the preceding page, the precipitation in 1909 was 31 percent below the average for 57 years. The lowest year for the period was 1866, when the precipitation was 60 percent below the normal, followed by 1867 with a precipitation 53 percent below the normal. (Table No. 1.) The accuracy of these records, however, is in considerable doubt. As regards precipitation and run off from the large rivers of the North-West ., the condition in 1909 resulted in severe water shortage.

We will now segregate the weekly minimum dischage and summer rainfall for these years :-

Variation in Percentage of Weekly Minimum Discharge and Summer Rainfall from the Average.

TABLE NO. 2

Name of River	Length of Record (years)	1905	1906	1909
Discharge :				
Columbia River	31	-22	-12	-7
Willamette River	19	-18	-6	+1
Deschutes River	6		-4	-4
John Day River	5	-33	+18	-35
Umatilla River	10	-25		-39
Naches River	6	+33	+9	-9
Tieton River	8	-7	-19	-30
Methow River	7	+11	-9	-15
Spokane River	11	-31	-24	
Clark Fork	4	-33	-22	
Summer rainfall	31	+17		-37

The figure for 1909 is particularly signicant. The rainfall during August and September is seen to be 37 percent below the average for 3I years. It should be remembered also that during the five to ten years comprising these records three exceedingly low years are included. It follows therefore that the average for the period of record is low, and as this average is used to determine the relative yearly variations it must be covered that the low-water conditions in I909 are more severe than would at first appear from the above table.

It would be conservative to use the mean discharge for the lowest week in I909 , Obtained by current meter measurement and records of gage hight as the minimum discharges for that particular point on the stream. (Plate Nos.7 & 8)

The Maximum or Flood Flow.

It is impossible to determine flood discharge with any degree of accuracy without actual gagings. The maximum rate of flow depends on the maximum rate of rainfall, the temperatures, the quantity of water stored as ice or snow at the time, the condition of the ground at the time of snowfall, the physical nature of the soil, the topography, the vegetation, the times of maximum rainfall and snow melting on tributary portions of the drainage area and the resultant combinations these will produce, and a multitude of other factors, all of which are practically unknown and almost indeterminable.

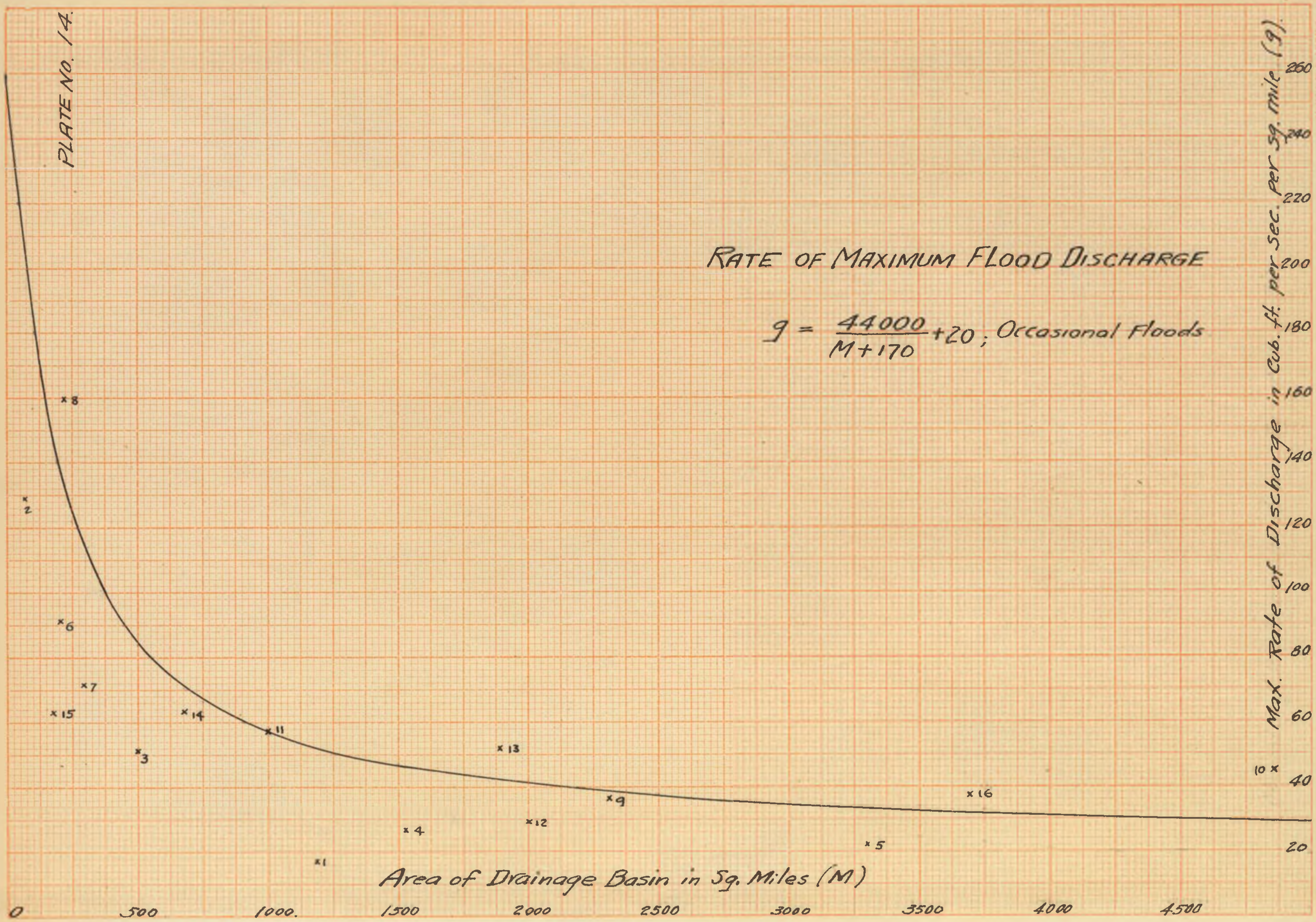
In the absence of the actual data , it is necessary to make a tentative estimate of the probable maximum discharge for preliminary study and design.

In order that such estimate can be made within reasonable limits, Mr. Knichling's formula for flood discharge is plotted in plate no. 14 and actual measurement of the several streams in the Cascade Range are also plotted in the diagram.

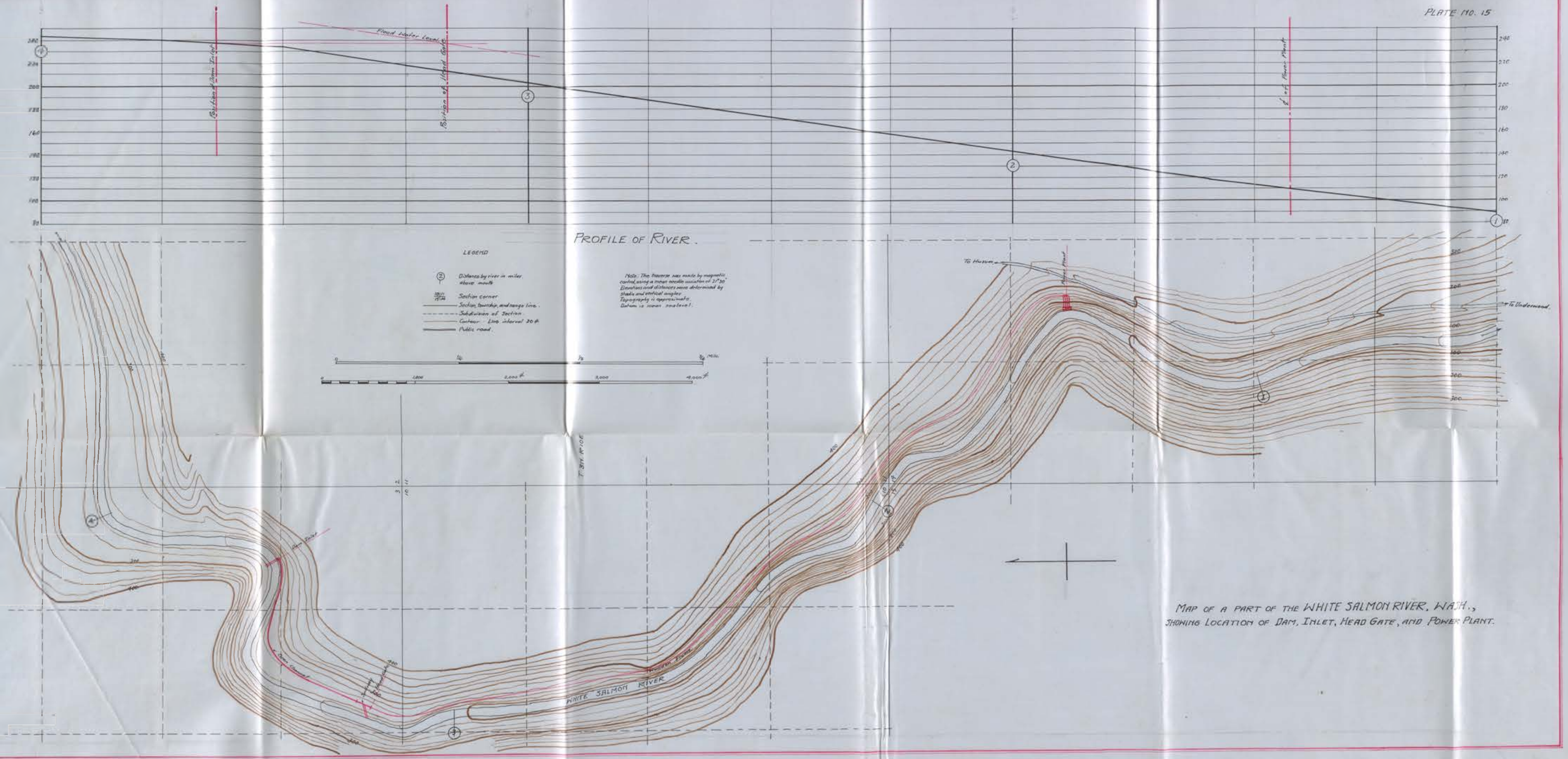
FLOOD DISCHARGE OF STREAMS DRAINING THE CASCADE RANGE.

NO	STREAM AND LOCATION.	Drainage Area Sq. Miles.	Date of Flood	Max. Disch. Cub-ft/Sec.	Max. Disch. Cub ft/Sec per M²
Streams Draining the Eastern Slope.					
1	Wenatchee River at Cashmere, Wash	1,190	Nov 30, 1909	20,700	17.4
2	Yakima River near Martin, Wash	56	Nov. 14, 1906	7,200	129.0
3	Yakima River at Clealum, Wash	500	do	25,600	51.2
4	Yakima River at Umtanum, Wash	1,540	Nov. 15 1906	41,000	26.6
5	Yakima River at Yakima, Wash	3,300	do	67,000	20.3
6	Clealum River at Roslyn, Wash	205	do	18,700	91.2
7	Tieton River near Naches, Wash	289	Nov 15 1906	21,000	72.7
Streams Draining the Western Slope.					
8	Cascade River near Marblemount, Wash	222	Nov. 29, 1909	40,000	160.0
9	Skagit River near Marblemount, Wash	2,340	do	86,000	36.7
10	Willamette River at Albany, Oreg	4,860	Dec. 8, 1861	220,000	45.3
11	North Fork of Unipqua River, Oreg	1,000	Jan 4, 1907	58,600	58.6
12	Rogue River near Tolo, Oreg	2,020	Nov. 23, 1909	60,000	29.7
13	Santian River at Jefferson, Oreg	1,890	Nov. 22, 1909	98,000	51.8
14	Clackamas River at Cazadero, Oreg	685	Nov. 22, 1909	46,800	68.3
15	Cedar River near Ravensdale, Wash	170	Nov. 15, 1906	10,800	63.5
16	Umpqua River near Elkton, Oreg.	3,680	Jan. 7, 1907	140,000	38.0
17	Mckenzie River near Springfield, Oreg.	960	Nov. 22, 1909	43,500	45.3

PLATE NO. 14.



RATE OF MAXIMUM FLOOD DISCHARGE
$q = \frac{44000}{M+170} + 20$; Occasional Floods
Max. Rate of Discharge in Cub. ft. per sec. per sq. mile (q)
Area of Drainage Basin in Sq. Miles (M)
0
500
1000.
1500
2000
2500
3000
3500
4000
4500
20
40
60
80
100
120
140
160
180
200
220
240
260
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16



MAP OF A PART OF THE WHITE SALMON RIVER, WASH., SHOWING LOCATION OF DAM, INLET, HEAD GATE, AND POWER PLANT.

As seen from the diagram that actual flood measurement of the several streams in the Cascade Range falls within the margin of the smooth curve of Mr. Knichling's proposed formula, excepting three cases among seventeen measurements, where these three cases are not seriously above the margin of the curve.

The flood discharge of the White Salmon River at Husum , Washington, therefore, may be determined by means of this formula:- Mr. Knichling's formula is

$$q = \frac{44000}{M + 170} + 20$$

q = Maximum rate of discharge cubic ft. per sec. per square mile.

M = Area of discharge basin in square miles.

Substituting the value of drainage area at the proposed dam site (near Husum) of the White Salmon River in the formula, we have the maximum rate of discharge (q) as 300 cubic ft. per second per square mile . Hence the drainage area at that section being 300 square miles, the total maximum discharge at that section is

$$300 \times 114 = 34{,}200 \text{ Cub. ft. / sec.}$$

Determination of the Flood Level.

Having the value of flood discharge and the cross section of the proposed site for dam, the following table is calculated by means of equation :-

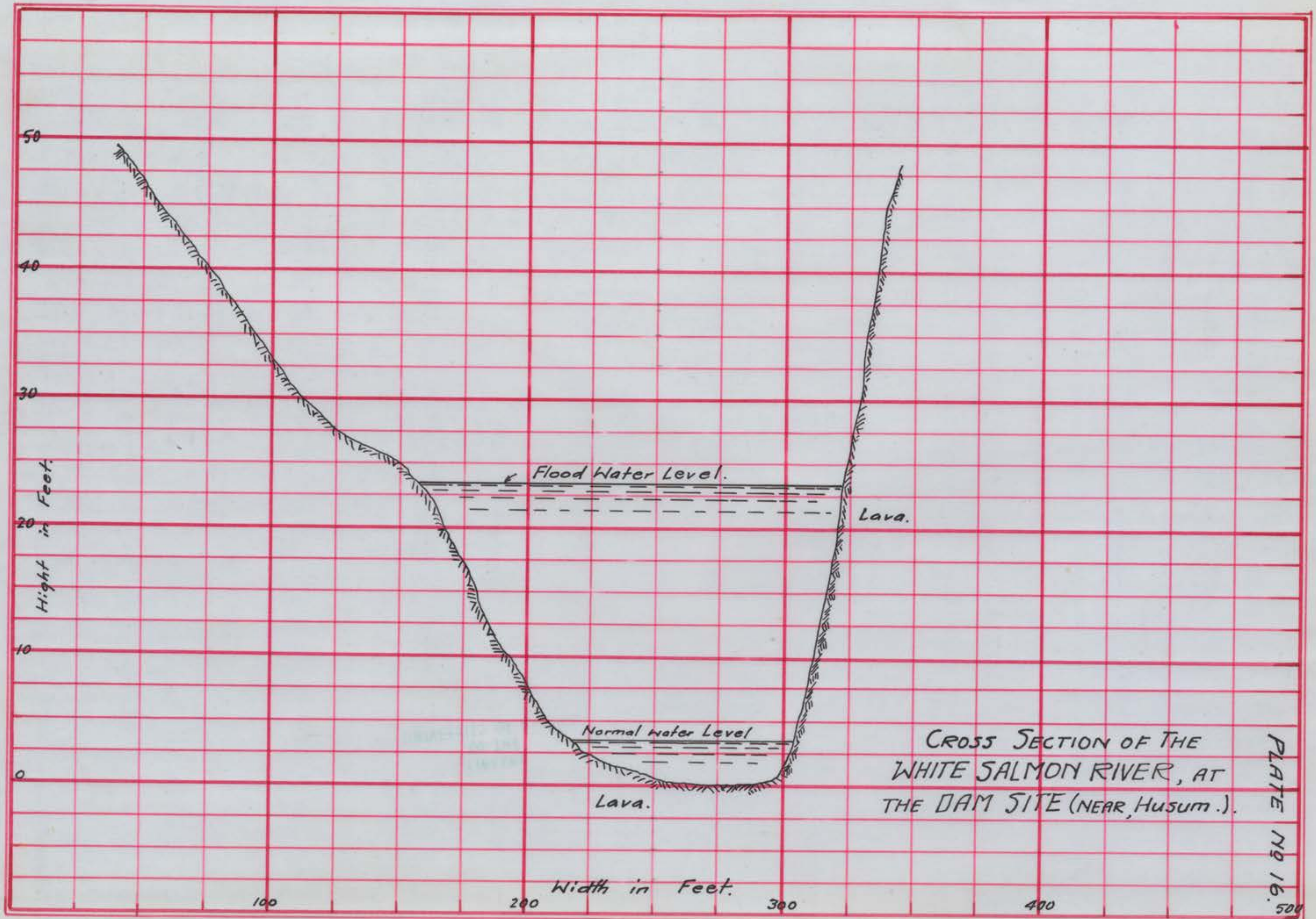
$$Q = V \times a = a \times c\sqrt{r\,s}.$$

Where Q = Discharge in cubic feet per second.

a = Cross sectional area in square foot. (Plate NO. 16)

c = Velocity coefficient.

r = Hydraulic radius.



CROSS SECTION OF THE WHITE SALMON RIVER, AT THE DAM SITE (NEAR, Husum.).

PLATE NO 16.

s Hydraulic slope.

V Velocity in feet per second.

For actual gage reading at low discharge the value of velocity coefficient (c) as calculated is about 20, but as a rule the value of c will increase with increase of discharge this is true especially in a rocky riversuch as that under consideration. For this reason in this calculation the value of c is assumed as 40 . The value of hydraulic slope (s) obtained from the profile (See, Plate No. 15), is about 0.006 .

Gage Hight		3.I2	20	30	35
Area	Sq. ft.	249	2,250	4,000	5,I25
p	ft.	93	I55	2I8	232
r	ft.	2.68	I4.5	I8.35	22.I
r x s		0.0I605	0.087	0.II	0.I325
$\sqrt{r \quad s}$		0.I266	0.295	0.33I	0.364
$V = c\sqrt{r \times s}$		2.5	II.8	I3.24	I4.56
Q		622	26,560	53,000	74,600

A graph is plotted by using this result (See, Part 7. Plate No. 40)on which the ordinates represent the gage height in feet and the abscissas the discharge in cubic feet per second. The flood level is determ ined from this graph as 23.5 feet in the gage height.

Power of the Stream.

A hydrograph at the proposed section of the dam site is constructed from the observed data of daily discharge in the summer I909. , in order that from the hydrograph a study of the stream flow and its influence on water power may be made.

The ordinate is the daily flow in cubic feet per square mile per second at the point of observation and the element of time the abscissa . (See, Plate No. 17) The result is a graphical diagram which shows the character and extent of the daily fluctuations in the flow of the stream at the point of observation during the period for which the hydrograph has been prepared.

The hydrograph , by a simple change in the vertical scale, may be made to show graphically the variations in the power of the stream. Assuming the proposed plant has a constant fall of 135 feet , the theoretical hyraulic horse power is then as follows :-

$$\text{H. P.} = \frac{Q \times \text{Drainage Area} \times \text{Head}}{8.8}$$

Q = Discharge cubic feet per second per square mile.

On account of losses due to the power development , the full theoretical power of the stream cannot be developed, and therefore assuming a loss of 30 percent of the useful power of the stream , an avaiable horse power may be developed :-

$$\text{A. H. P.} = \frac{Q \times \text{Drainage Area} \times \text{Head} \times .70}{8.8}$$

For a discharge of 1 cubic foot per second per square mile at the proposed dam site, (See, Plate No. 17) we have

$$\text{A. H. P.} = \frac{1 \times 300 \times 135 \times .70}{8.8} = 3,220$$

The value of horse power that can be developed is recorded by the vertical scale according to the discharge on the hydrograph. And we find from the graph that the minimum power that can be obtained from the stream is about 4,830 horse power

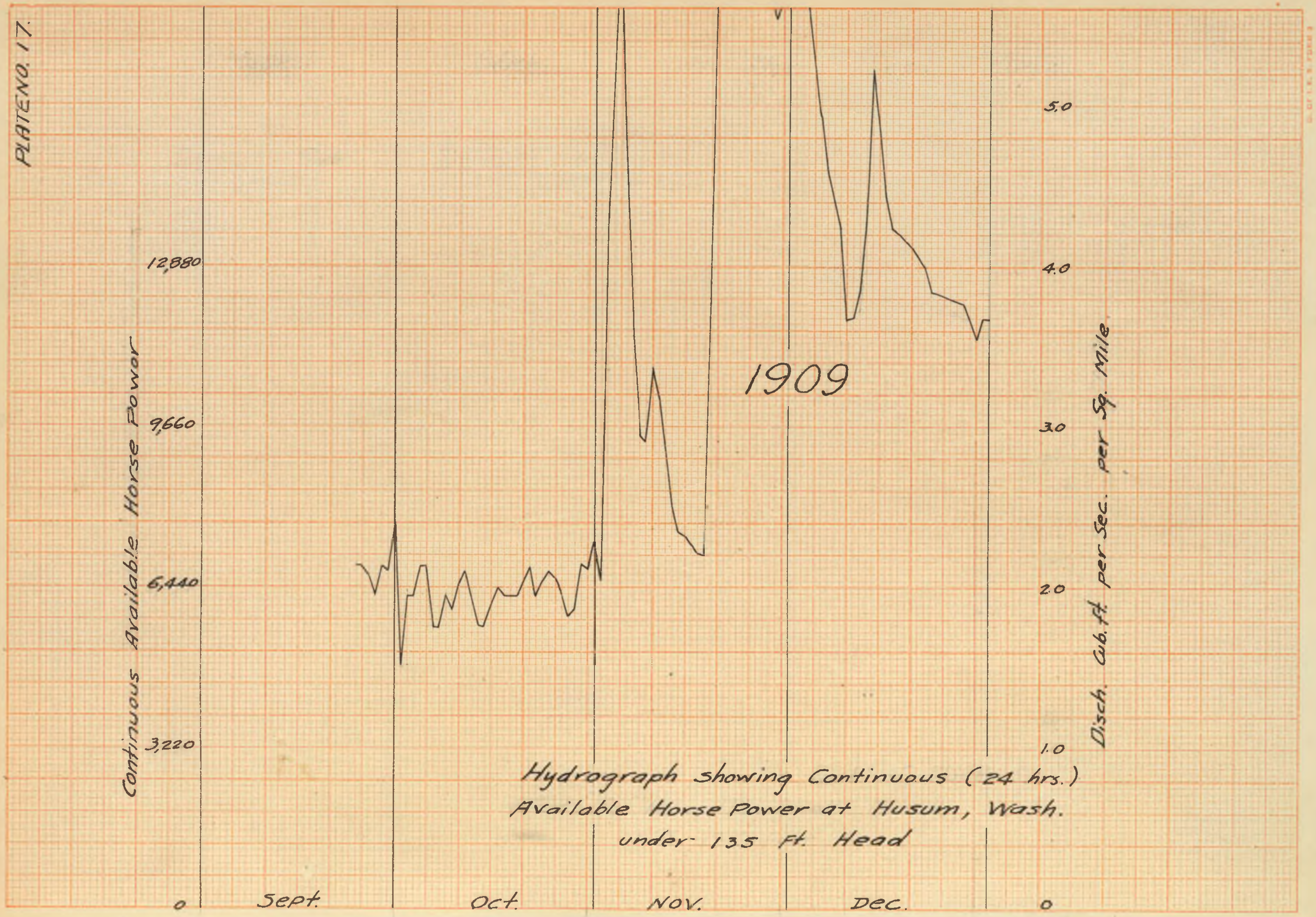


PLATE NO. 17.

Hydrograph showing Continuous (24 hrs.) Available Horse Power at Husum, Wash. under 135 Ft. Head under the head of I35 feet.

As we described in part I of this book , the approximate power demand for our enterprise is about 2,000kilo watts of electric energy at its winter peak load . (See, Plate No. 2.)

From the careful investigation of the stream we have learned that the stream can furnish the required water power even at the lowest discharge , with a good deal of margin.
We are now, therefore, ready to find out the exact power comsumption or in other words to find out losses due to the mechanical , electrical, and hydraulical development.
As matter of order the transmission system will be described and discussed in the next part.

PART 3 .

Transmission Line .

Transmission system.

The general map of transmission system shows the extent of the transmission system to be constructed. There are 95.5 miles of line sectionalized as shown in the table below:-

Nomenclature of Sections	Miles	Circuits
No. I Power plant to Goldendale	52	I
No. 2 Power Plant to The Dalles	23	I
No. 3 Power Plant to Stevenson & including to Husum	20.5	2

It will be noted that while two circuits are erected in the section no. 3 , only one circuit is erected through out the rest of the system. The reason for this is apparent upon examination of the general plan of the system. All the sections, except section no. 3 , are on the loop circuit and as a result may be served from the central station in either direction around the loop.

Transmission Conductors.

General Consideration.

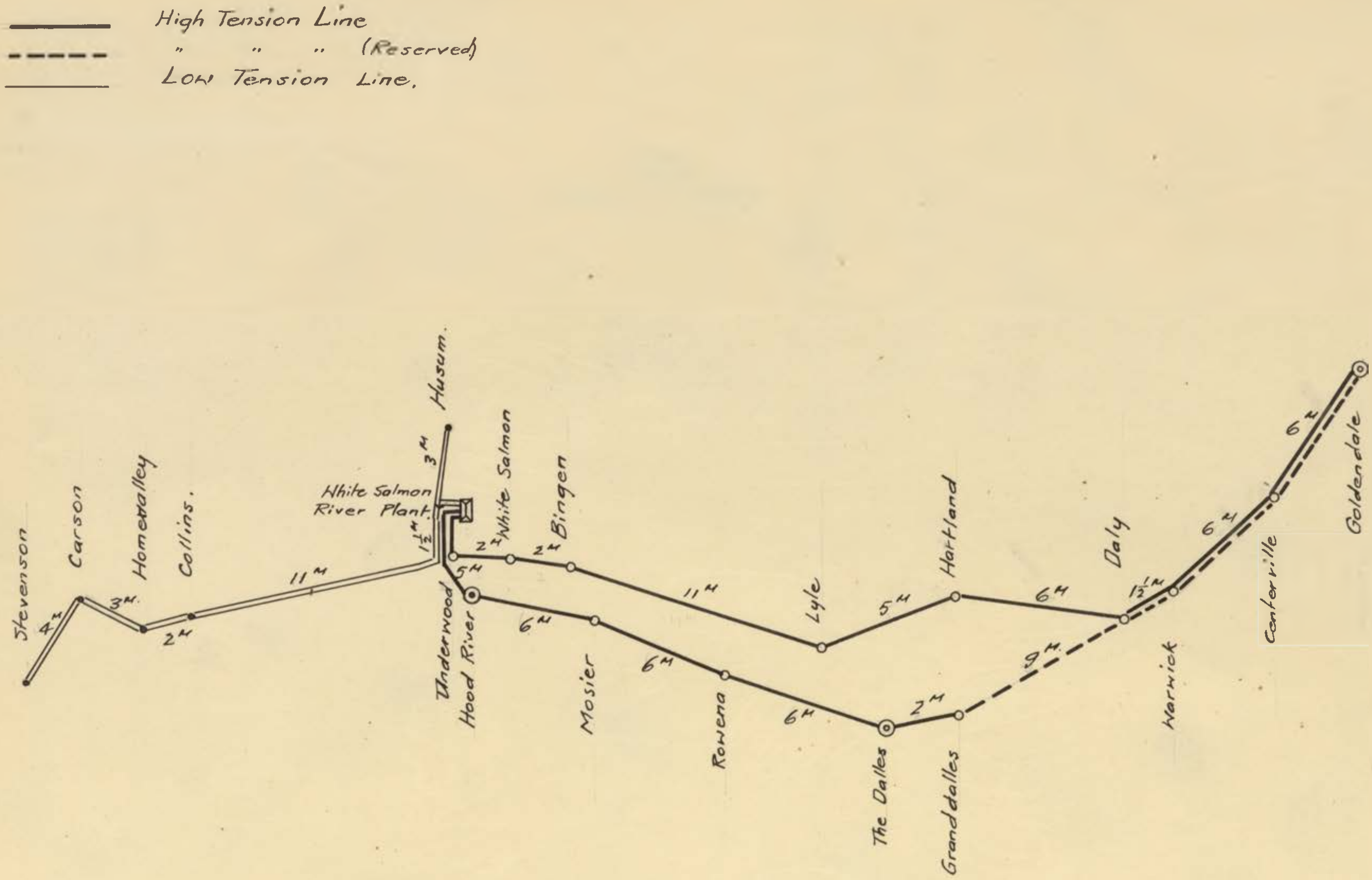
When a system of conductors is to be designed there are at least eight points that must be considered :-

I Conductors must be so proportioned as to be within safe heating limits.

2 Conductors must be so proportioned as to be mechanically strong;

3 Conductors may be designed for minimum first cost of

PLATE NO. 18



MAP OF TRANSMISSION SYSTEM.

line construction ;

4 Conductors may be planned for minimum first cost of central station ;

5 Conductors may be designed for minimum first cost of operation and maintenance ;

6 Conductors may be designed for min. total installation cost ;

7 Conductors may be designed to secure to the customer certain predetermined service conditions.

8 Conductors may be calculated to attain a maximum income with a minimum cost.

The foregoing conditions are in many respects incompatible and therefore cannot all be realized in any one plant. The plant in question , therefore is designed for most economical size of conductors for constant voltage system with distributed loads.

The voltages for the sections Nos. I & 2 are decided to be 33,000 volts, and for the section no. 3 is to be 6,6oo volts . Now from the inventory, we have found the electrical energy to be delivered at each town. The results are tabulated on the plate no. 19 . All the known items and other conditions on the line are also tabulated on the same plate.

Determination of the size of conductors .

When it is desired to reduce the size of a pair of service mains in steps so as to secure the greatest economy of copper, the size of each portion of the mains is determined as follow:

Assuming the total drop to be allowed out to the end of the line , the factor (s) is calculated from the equation :-

Voltage	33,000	Frequency	25
Phase	3	Power Factor	85
Conductor	Copper	Phase Voltage	17,320

Line Loss assumed 3 per cent.

Name of Town.	Distance from Plant. Miles	Demanded Load. K.W.	Total Load including Line Loss. KW.	Apparent Energy to be Deliverd W	Total Load Per Phase KW	Current Per Line Amp.
Section No 1						
Goldendale	41	534	550	216,000	183.5	12.5
Centerville	35	19.4	570	224,000	190.0	12.95
Warick	29	6.8	577	226,100	192.2	13.05
Daley	27½	6.8	584	229,000	194.6	13.25
Hartland	21½	9.7	594	233,000	198.0	13.45
Lyle	16½	6.8	601	235,600	200.5	13.60
Bingen	5½	13.6	615	241,000	205.0	13.90
White Salmon.	3½	22.3	638	250,000	212.7	14.45
Underwood	1½	29.1	668	262,000	222.7	15.1
Section No 2						
The Dalles.	19	873	900	353,000	300.0	20.4
Rowena	17	29.1	930	365,000	310.0	21.1
Mosier	11	126	1060	416,000	353.3	24.02
Hood River	5	291	1360	534,000	453.3	30.9

Section No 3

Voltage	6,600	Frequency	25
Phase	3	Power Factor	85 %.
Conductor	Copper	Phase Voltage	3,810

Line Loss assumed 3 per cent of load

Stevenson	19½	97.0	100	39,200	33.3	10.3
Carson	15½	13.6	114	43,600	37.1	11.4
Homevalley	13½	6.8	121	47,400	40.3	12.5
Collin	11½	6.8	128	50,250	42.7	13.4
Husum.	3.	24.3				

Methods of calculation used are:

$$\text{Apprent Energy Deli.} = \frac{\text{Total Load per Phase}}{\text{Power Factor}}$$

$$\text{Line Current} = \frac{\text{Apparent Energy Del.}}{\text{Phase Voltage}}$$

$$s = \frac{3 \times 10.8 \times (a\sqrt{i_1} + b\sqrt{i_2} + c\sqrt{i_3} + ---)}{\text{Total drop in volts}}$$

Where a, b, c, --- are the length in feet of the respective portions of the pair of mains, and i_1, i_2, i_3, --- are the current in amperes in the respective portions . The sectional areas of the mains in circular mils are then equal to $s\sqrt{i_1}$, $s\sqrt{i_2}$, $s\sqrt{i_3}$, ---- respectively .

On the plate no. 19 we have all figures for the calculation of the value of s, and substituting these figures into the equation :-

For the section no. I .

$$s = \frac{32.4 \times 5280 \times (19.5 \times 3.53 + 20 \times 3.67 + 1.5 \times 3.88)}{33,000 \times 0.05}$$

$$= 22,100$$

Then the size of wire for the section no. I .

22,100 x 3.88 = 86,000 Cir. Mils. (Plant to Underwood)

B & S # 0 wire is to be used.

22,100 x 3.67 = 81,000 Cir. Mils.

and

22,100 X 3.53 = 77,900 Cir. Mils.

B & S # I wire is decided to be used between from Plant to Goldendale .

For the section No. 2 .

$$s = \frac{3 \times 10.8 \times (10 \times 4.51 + 9 \times 4.9 + 5 \times 5.55)}{33,000 \times 0.05}$$

$$= 12,150$$

From Plant to Hood River

12,150 x 5.55 = 67,500 Cir . Mils .

From Hood River to Mosier

I2,I50 x 4.9 = 59,500 Cir. Mils.

From Mosier to The Dalles

I2,I50 x 4.5I = 54,800 Cir. Mils.

The sizes of wires are increased one number respectively from the sizes obtained from the above calculation , for the reason of mechanical strength. We have , therefore ;

From Plant to Hood River B. & S. # I Wire

From Hood River to Mosier B. & S. # 2 Wire.

From Mosier to The Dalles B. & S. # 2 Wire .

For the section no. 3 :-

$$s = \frac{3 \times 10.8 \times 5,280 \times (11.5 \times 13.4 + 8 \times 10.3)}{6,600 \times 0.1}$$

$$= 17,620$$

For this section I0 % voltage drop allowed. Then the sizes of wires to be used for this section are :-

From Plant to Collins

I7,600 x 3.66 = 64,500 Cir. Mils.

B. & S. # 2 Wire .

From Collins to Stevenson

I7,600 x 3.2I = 56,500 Cir. Mils.

B. & S. # 2 Wire .

Determination of the Spacing of the Conductors .

The spacing of conductors depends on the voltage and the length of the spans. The increase in spacing increases the inductive drop, and also the line loss. There are no fixed rules established for the spacing of conductors .

However , from the consideration of the first two factors the spacing of conductors for this trasmission system has been taken as follows :-

For 33,000 volts line 60 inches.

For 6,600 volts line 36 inches.

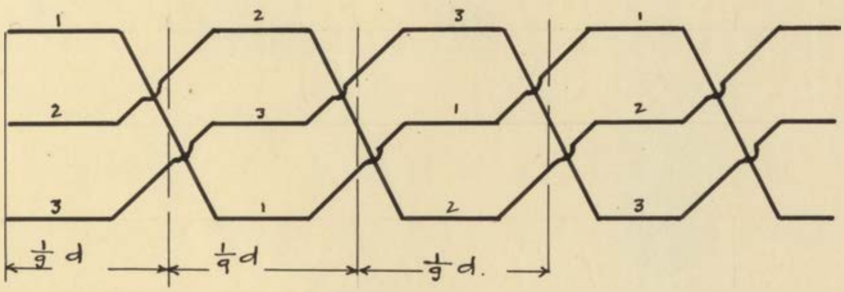
Calculation of Necessary Voltage at Sending and Receiving Ends.

(See Plates No. 20 & 21.)

The charging and Corona effect on the transmission system is neglected throughout this calculation, since the both effects will be negligibly small.

Transposition of the Conductors.

Excessive inductive effect can be counter acted by transposing the conductors. In the final transposition the phases must occupy the same relative position as at the beginning. This arrangement is shown diagrametrically below.



d = Total distance.

Table of Physical and Electrical Constants of Copper Wire Calculated for Matthiessen Standard.Wire At 60 degrees F. for Transmission Line Calculation

Size of Wire B & S.	Dia. in inches	Area in Cir. Mils.	Spacing in inches	Resistance per 1 wire per mile.	Inductive Reactance per mile of 1 wire Ohms	Weight per mile per Wire lbs.
0	.3248	105592	60	0.5085	0.3118	1,690
1	.2898	83694	60	0.6440	0.3178	1,335

Continued on next page

1	0.2898	83694	36	0.644	0.2915	1,335
2	0.2576	66373	60	0.808	0.3233	1,057
2	0.2576	66373	36	0.808	0.2973	1,057

The figures in this table are used for the calculation of transmission line on the plates nos. 20 & 21 .

Pole Line and Accessories.

Economical spans.

In laying out a transmission line it is of foremost importance first, to find out the most economical span, that is, after the size of the conductors has been calculated. The consideration of economical sizes of conductors were found and for these conductors the spans are to be 250 feet for # I B. & S. and 2I0 feet for # 2 B. & S.

Line stress.

The spans have been determined and now we should have the sags due to these spans. When a wire is suspended between two supports it takes a curve known as the catenary. In the case in hand the catenary will be very close to theparabola, which gives the following relations:-

$$H = \frac{L^2 w}{8 f}$$

H = Tension in cable at ends;

L = Length of span in feet ;

w = Weight per foot of wire;

f = The central deflection in feet or sag in feet.

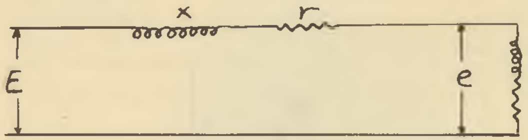
The strength of conductors is determined by use of this formula on given spans .

PLATE NO 20

TRANSMISSION LINE CALCULATION

SECTION NO. 1. P.F. 85, Freq 25, Spacing 60".

Size of Wire.	B&S. Gage No 2.								B&S No 2
Distance Miles	6.	6	$1\frac{1}{2}$	6	5	11	2	2	$1\frac{1}{2}$
e	17320	17385	17452	174688	17537.5	17595.6	17725.5	17749.8	17775
I	12.5	12.95	13.05	13.25	13.45	13.60	13.90	14.45	15.1
i	10.6	11.00	11.10	11.25	11.42	11.55	11.82	12.26	12.82
i_1	6.65	6.82	6.87	6.98	7.08	7.16	7.32	7.6	7.95
r	4.86	4.86	1.211	4.86	4.04	8.89	1.616	1.616	.967
x	1.94	1.94	.485	1.94	1.615	3.66	.646	.646	.476
ir	51.5	53.4	13.45	54.7	46.2	102.7	19.1	19.8	12.4
i_1x	12.9	13.2	3.33	13.5	11.45	26.2	4.73	4.92	3.78
$e+ir+i_1x$	17384.4	17451.6	174687.8	17537	1759515	17724.5	1774933	1777452	17791.18
i_1r	32.3	33.1	8.32	33.9	28.62	63.7	11.82	12.3	7.68
$-xi$	-20.6	-21.4	5.38	-21.8	-18.45	-42.3	-7.64	-7.92	-6.11
$j\ ri_1-ix$	11.7	11.7	2.9d	12.1	10.17	21.4	4.18	4.48	1.57
E	17385	17452.	17468.8	17539.5	17595.6	17725.5	177498	17775.	17792
Drop									472
Reg in %.									2.73.



$$E_0 = e + \dot{I}Z = e + (r - jx)(i + ji_1)$$

$$= e + ir + i_1x + j(i_1r - xi)$$

$$E = \sqrt{(e + ir + i_1x)^2 + (i_1r - xi)^2}$$

Section № 2

P.F of Load .85 , Freq 25, Spacing 60"

Size of Wire	B&S Gage № 2			B&S № 1
Distance, Miles	6	6	6	5
e	17320	17422	17531	17654
I	20.4	21.1	24.02	30.9
i	17.35	17.95	20.4	26.3
i_1	9.14	11.1	12.65	16.25
r	4.85	4.85	4.85	3.22
x	1.94	1.94	1.94	1.59
ir	84.2	87.0	97.5	99.4
i_1x	17.6	21.5	24.6	25.8
$e+ir+i_1x$	17421.8	17530.5	17653.1	17914.4
i_1x	44.3	53.9	61.4	52.3
ix	- 33.7	- 34.8	- 39.6	- 41.8
$j(i_1r-ix)$	10.6	19.1	21.8	10.5
E	17422	17531	17654	17880
Drop				560.
Reg in %.				3.2

Section № 3

P.F. of Load .85 , Freq 25, Spacing 36"

Size of Wire	B&S. Gage № 2			
Distance in Miles	4	3	2	11 1/2
e	3,620	3655	3682.5	3704.
I	10.3	11.4	12.5	13.4
i	8.76	9.68	10.62	11.4
i_1	5.42	6.00	6.58	7.06
r	3.23	2.42	1.62	9.28
x	1.19	.892	.594	3.42
ir	28.3	21.75	17.27	106.
i_1x	6.45	5.77	3.92	24.2
$e+ir+i_1x$	3654.8	36821.	3703.7	3834.2
i_1r	17.5	14.5	10.6	65.6
ix	- 10.4	- 8.67	- 6.32	- 39.0
$j(i_1r-ix)$	7.1	5.83	4.28	26.6
E	3655	3682.5	3704	3835
Drop				215
Reg in %				5.95

Calculation of strength of # I wire .

Diameter = 0.2893 inches .

Area = 83,690 c.m. or 0.0656 sq. inch.

Weight = 0.25288 lbs. per liner foot.

Elastic Limit = 2,295 lbs. or 35,000 lbs. per sq. in.

Wind Pressure = I8 lbs. per sq. ft. (counting diameter into length as the exposed area) .

Taking the weight of ice as 0.0332 lbs. per cub. inch the weight per foot of 0.5 inch coat of ice on the wire is

$$0.0332 \times I2 \times \frac{\pi}{4}\left[(I.2893)^2 - (0.2893)^2 \right] = 0.489 \text{ lbs.}$$

Therefore the total weight of ice and wire and the wind pressure on the wire with its ice covering would be, respectively

$$0.25288 + 0.489 = 0.742 \text{ lbs. per foot .}$$

$$I.289 \times I2 \times I8 / I44 = I.935 \text{ lbs.}$$

But these weights act at right angle to each other , and therefore the resultant force acting on the wire is,

$$w = \sqrt{\overline{0.742}^2 + \overline{I.935}^2} = 2.07 \text{ lbs. per lin. ft.}$$

The permissible strain in the wire , if taken at 2/3 of the elastic limit , would be

$$2/3 \times 2,295 = I,530 \text{ lbs.}$$

Tabulating the data given above , together with the quantities to be determined ,

l = length of span = 250 feet .

f = sag at minimum temperature (-20° F)

f_1 = sag at higher temperature

H = tension at lowest point of wire at minimumtemperature I,530 lbs.

H_1 = tension at lowest point of wire at higher tempature.

w = resultant weight = 2.07 lbs. per lin. ft.

L = length of wire in span at minimum temperature .

L_1 = length of wire at higher temperature.

T = temperature range (130° F).

a = coefficient of linear expansion for copper = 0.00000956 .

From the equation , we have the sag at minimum temperature to be

$$f = \frac{l^2 w}{8H} = \frac{250^2 \times 2.07}{8 \times 1,530} = 10.5 \text{ feet.}$$

$$L = l + \frac{8f^2}{3l} = 250 + \frac{8\,(\,10.5\,)^2}{3 \times 250} = 251.72 \text{ feet}$$

$$f_1^3 - f_1 \left[f^2 + \frac{3lL}{8}\left(aT - \frac{H}{AE} \right) \right] - \frac{3lLfHw_1}{8AEw} = 0$$

When the ice coating disappears the pressure on the wire due to wind is

$$0.289 \times 12 \times 18 / 144 = 0.434 \text{ lbs. per lin. ft.}$$

The total weight therefore

$$w_1 = \sqrt{\overline{0.2529}^2 + \overline{0.434}^2} = 0.501 \text{ lbs. per lin.ft.}$$

Substituting these values

$$f_1^3 - 104.88\, f_1 - 86.9 = 0$$

$$f_1 = 10.65 \text{ feet}$$

The tension in the wire when both temperature and wind reach a maximum

$$H_1 = \frac{l^2 w_1}{8f} = \frac{\overline{250}^2 \times 0.501}{8 \times 10.65} = 367 \text{ lbs.}$$

$$H - H_1 = 1,530 - 367 = 1,163 \text{ lbs.}$$

$$L = l + \frac{8f^2}{3l} = 250 + \frac{8\,(\,10.65\,)^2}{3 \times 250} = 251.2 \text{ feet}$$

Calculation of strength of No. 2. B. & S.

With using the same formula the No. 2 B. & S. is calculated. This result is taburated as below :-

Diameter = 0.2576 inch.

Area = 66,370 c. m. or 0.0521 sq. in.

Weight = 0.20054 lbs. per lin. ft.

w = 1.975 lbs. per lin. ft.

l = 210 feet

f = 8.5 feet

L = 210.92 feet

H = 1215 lbs.

w_1 = 0.435 lbs. per lin. ft.

f_1 = 8.64 feet

H_1 = 314 lbs.

$H - H_1$ = 901 lbs.

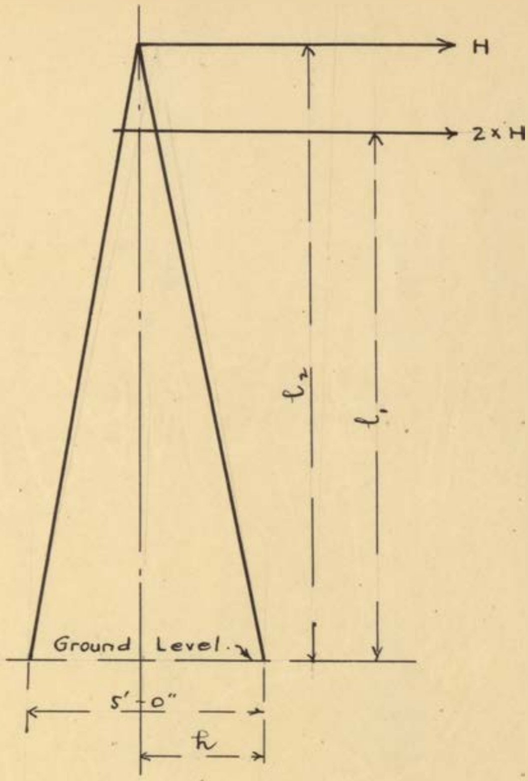
Supporting pole.

The transmission line runs through the forest district in Washington, where wooden poles may be obtained very cheaply and without transportation. Therefore for this reason and ease of erection the wooden pole is chosen, except 4-steel towers which are to be used at two points, where the transmission lines cross the Columbia River.

Strength of wooden pole.

The strain acting on a pole tending to pull it over at the top is the most important one to be considered.

In calculation of sag, we have obtained the maximum tension of wire that can act on the pole. This value for # 1 wire of 250 ft. span is 1,530 lbs. per wire. The forces then acting on the pole are shown on the diagram below.



Side Elevation

l_1 = hight of pole from ground to the arm 35.67 ft.

l_2 = hight of pole from ground to the top 40 ft.

h = 2.5 ft.

Taking the moment to these forces .

$$M = (1530 \times 40 + 3060 \times 35.67) \times 12$$

$$= 2{,}0420{,}000 \text{ in.lbs.}$$

Assuming the strength of wood with 10 factor of safety 800 lbs. per sq. in. = S

Then

$$S = \frac{M\,h}{I}$$

I = The moment inertia .

Where I in this case ;

$$I = I' + A\,h^2$$

I' = moment inertia of the pole section

A = area of the pole section in sq. in.

d = diameter of the pole in inches.

Then

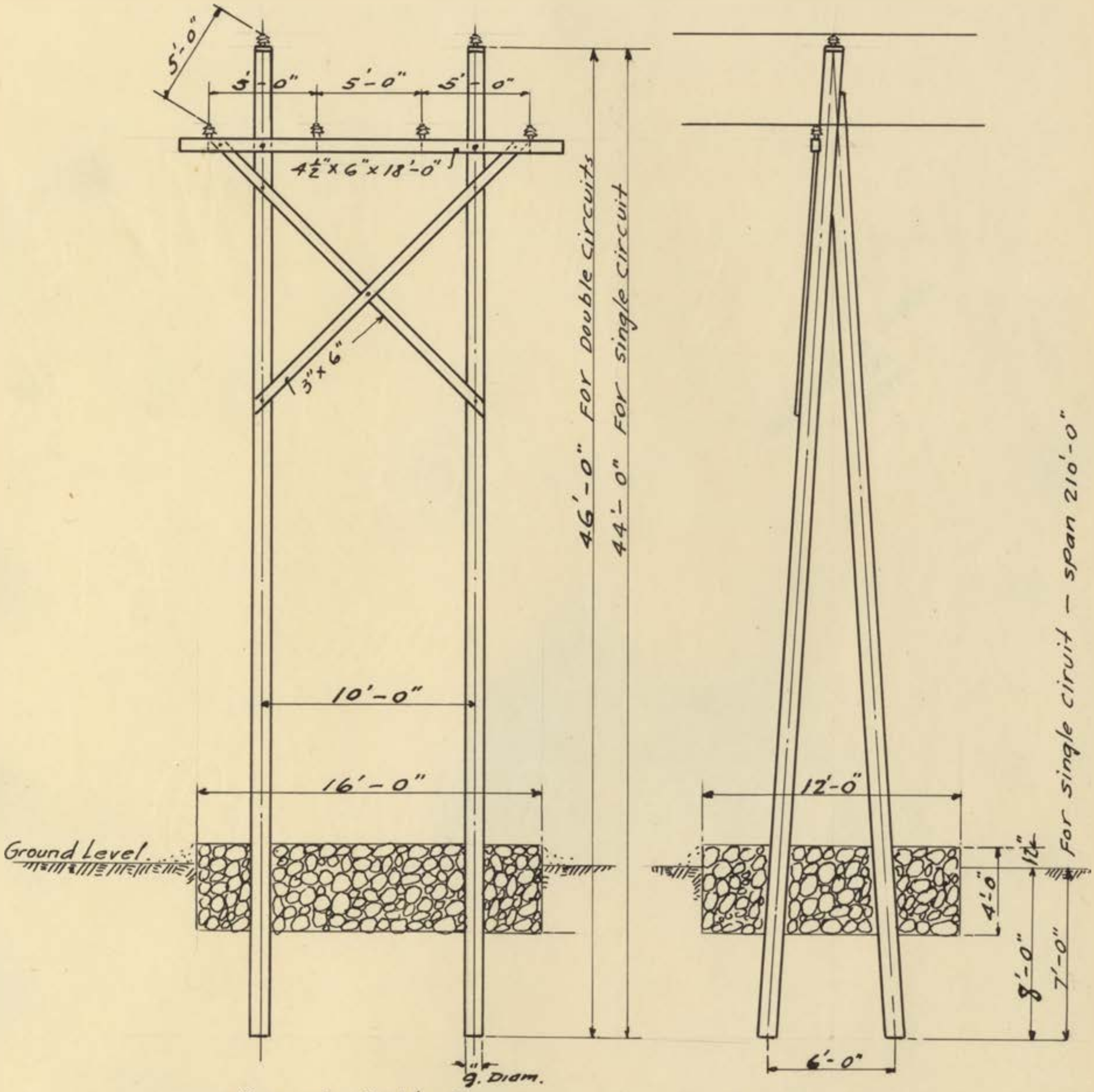
$$I = 2 \times \frac{\pi d^4}{64} + 2\left(\frac{\pi d^2}{4} \times h^2\right)$$

Where $2\frac{\pi d^4}{64}$ is negligibly small compared with $A\,h^2$ and therefore may be ommitted.

$$800 = \frac{170{,}400 \times 12 \times 2.5 \times 12}{\pi d^2/4 \times (2.5 \times 12)^2 \times 2}$$

Solving for d ; $d = \sqrt{60.4} = 7.8$ in. dia.

The detail of pole construction will be seen on the plate no. 22 . Where only wooden pole for double circuit



Pole for Double Circuits

Side Elevation.

Scale 1/8" = 1'-0"

Wooden Pole for High Tension Transmission Line.

line of 250 feet span is shown (high tension) , but for single circuit the construction is exactly the same , except where only one pair pole is used instead of double pair of poles . The pole for 2IO feet span is constructed practically the same as the 250 feet span's . The differences are indicated in the part of the estimation of cost of transmission line , at the end of this book .

Kind of wood .

Pine is used in the pole line constructions , although this tree has the disadvantage of a short life and inferior strength . But this tree is chosen owing to its cheapness in first cost .

Cross arm .

The cross arms are made of first class wood , such as chestnut , white oak or ceder. The standard sizes are to be used on the poles as following :-

For high tension double circuits 6" x 4.5" x I8'-0".

" " " single circuits 6" x 3.25" x 7'-0".

" low tension double circuits 6" x 3" x I0'-0".

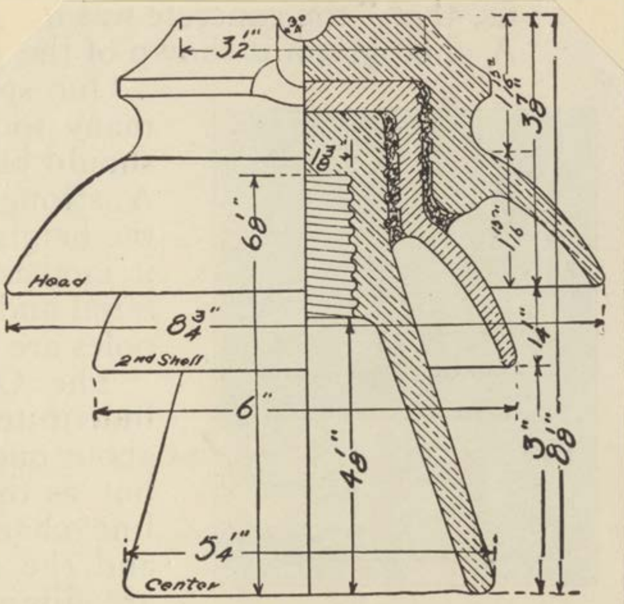
Insulator .

The prime requirement for the insutator is a high insulating quality and it must also posess mechanical strength .

For this reason porcelain insulators are used . The insulator for high tension line is shown on plate no. 23.

Insulator pin .

The insulator pin to be used in the transmission line is an iron bolt with a wooden top which screws into the insulator , and is provided with a porcelain base, so as to avoid burning out of the pin.

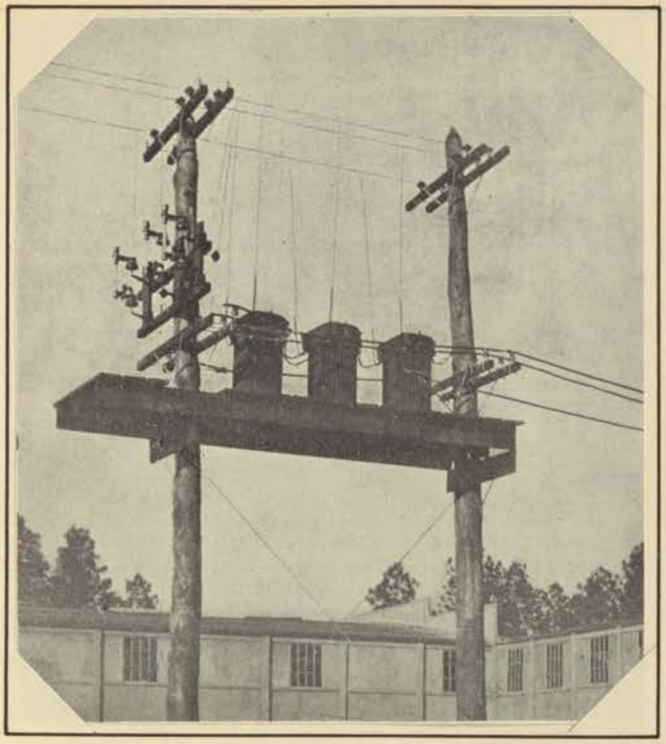


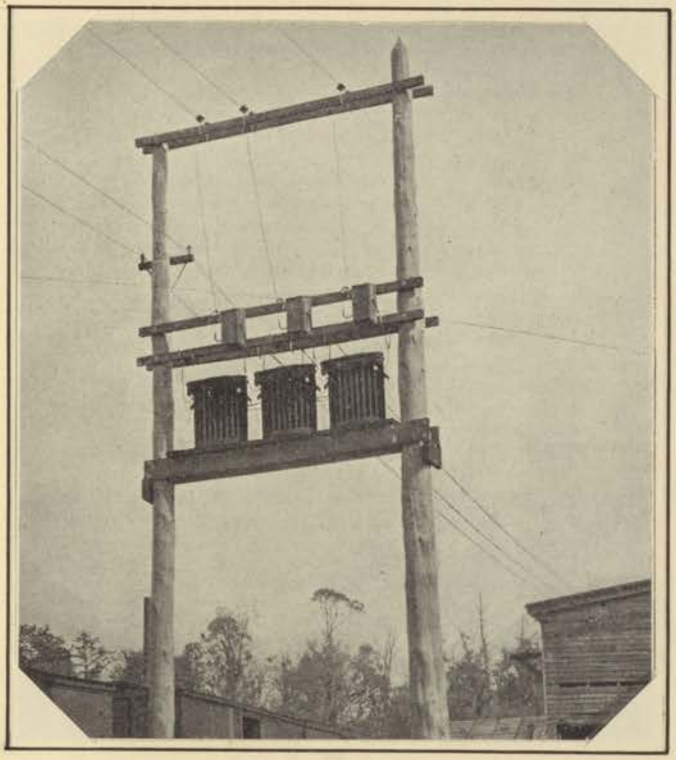
Line Voltage 33,000
Dry Test Voltage 90,000
Rain Test Voltage 65,000

Insulator

Section switches .

Section switches are located near Daley and near Underwood , (See , Plate No. 18)so that , in cases , defective sections may be easily cut out and by passed.





TRANSFORMER INSTALLATION FOR DISTRIBUTION OF LOAD

PART 4

Electrical Equipment.

From the study on the transmission system , and the power demand at the markets , we have all necessary data and required items for the determination of electricl equipment on the power plant .

Transformer .

General Consideration .

In the foregoing part we have chosen 3 phase, 33,000 volts for the high tension and 3 phase, 6,600 volts for the low tension of the transmission system. In order to reduce these voltage to a reasonable voltage on dynamos at the plant, step up transformers are used at the plant on the beginning of the out-going transmission lines.

The main reasons for reducing the line voltages at the plant are :-

I By using trasformers reduce danger at the plant.

2 Reduce the cost of switch board.

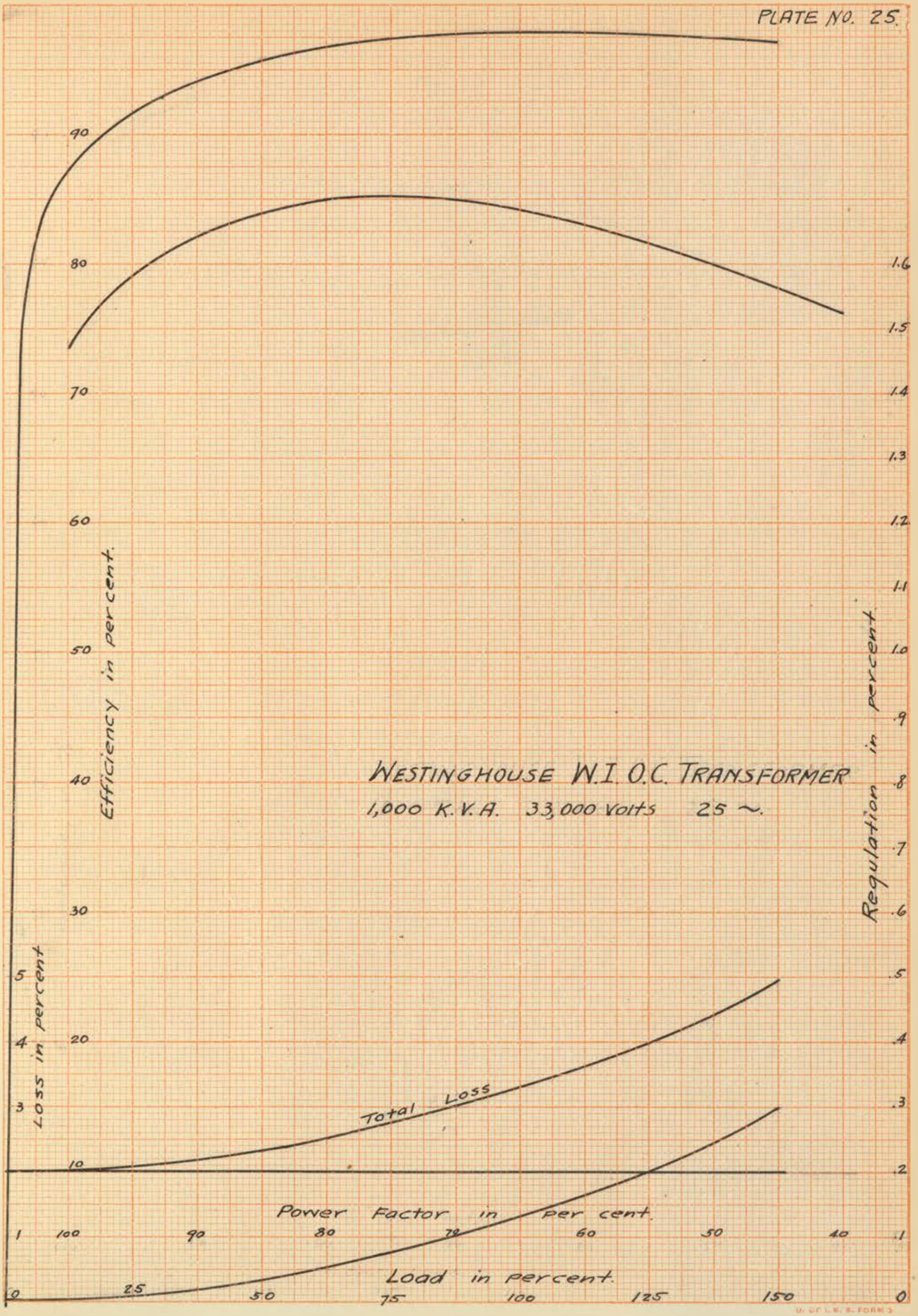
3 Reduce the price of dynamo.

Type of transformer.

Due to abundance of water at the station , oil insalated, water cooled transformers are chosen.

Regulation of the transformer .

The regulation of a transformer depends largely upon the resistance drop, and the inductive drop within it . The former is fixed by the amount of copper loss at full load, the latter by the number of turns in the winding and the relative position of the coils and the spacing between them. In large transfomers for long distance transmission , close


WESTINGHOUSE W.I. O.C. TRANSFORMER
1,000 K.V.A. 33,000 Volts 25 ~.
Efficiency in per cent.
Regulation in percent
Loss in percent
Total Loss
Power Factor in per cent.
Load in percent.
90
80
70
60
50
40
30
20
10
5
4
3
1
0
100
90
80
70
60
50
40
25
50
75
100
125
150
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0

regulation is very important . The regulation curve will be seen on Plate No.25.

Efficiency .

The efficiency of transformer depends upon the losses, which are of two kinds, iron loss and copper loss. The iron loss is due to magnetic reversals in the iron. The copper losses result from the passage of current through the conductor. The efficiency curve of the transformers are plotted on the plate no.25, of which the size of transformer required is determined.

Determination of Unit of transformer.

From a study of the load curve (Plate No. 2), and the calculated results of transmission line (Plate No.20 & 21), the following units are recommended.

For the high tension lines.

3 Units, 3 phase, I,000 K. V. A., 25 ~ ,

33,000 to 2,200 volts, W. C. , O.I., transformers.

The two of these units would be in service for daily load, and during the winter peak load these two transformers may be operated under over load for about two hours. One unit is therefore , installed as emergency unit.

For the low tension line.

I Unit, 3 phase, 200 K. V. A., 25 ~ ,

Voltages ratio; 6,600 to 2,200 , W.C., O.I., Transformer.

This unit takes care the load on the section no.3.

Alternator.

Given items .

From the foregoing parts the fixed items for alternator are:-

Voltage 2,200.

Phase 3

Frequency 25.

The reason of which we have chosen this frequency is omitted on the foregoing part, therefore , it might be worth while to explain this matter.

The most common frequencies used are 25 and 60, which one is used depends chiefly on the charactor of service. In this plant the lower frequency is chosen , because the principal service of this plant is for power purposes;where synchronous machines, such as rotary convertors, give more trouble on 60 cycle.

Type of Alternator.

The revolving field alternator is selected, for the following reasons.

I The method of construction facilitates the insulation of the armature winding.

2 Requires that field current instead of the armature current pass through the collector rings and brushes.

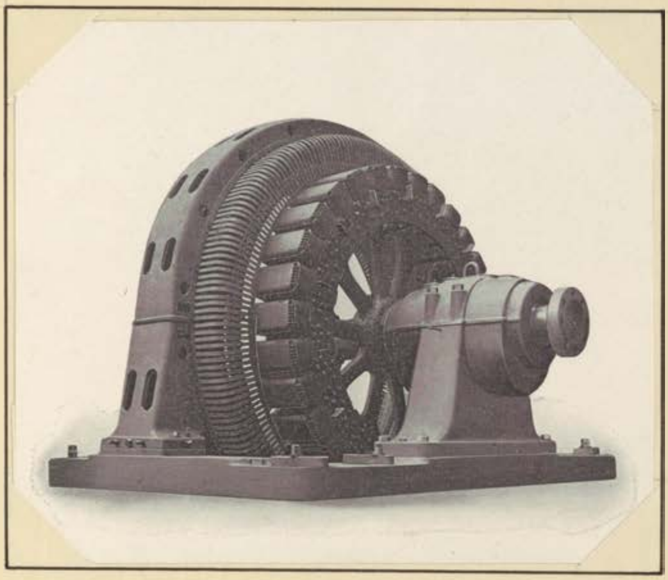
3 Cheaper than induction machine.

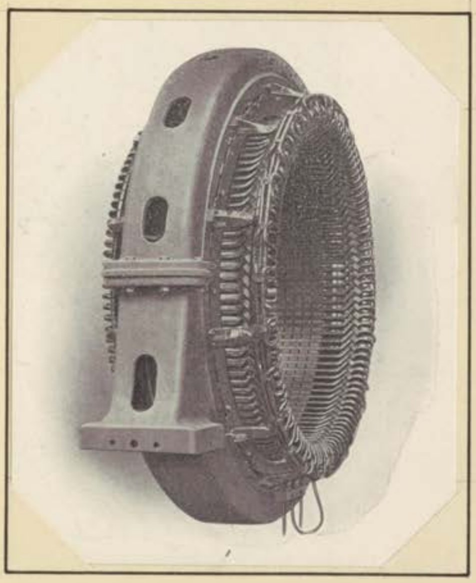
Selection of unit of machines.

With the same reasons that we have considered in the selection of transformer capacities, 3 units of alternators of I,000 K. W. are chosen .

Operation of the machines.

An examination of load curve (See, Plate No. 2) shows that the summer load runs about 9 months out of year and during these months 2 units of I,000 K. W. machines would be operated in parallel for I3 hours daily , for the II hours





ALTERNATOR

3 Phase 1,000 K.W.

250 R.P.M.

2,200 volts

daily the one I,000 K. W. machine would be run. One I,000 K. W. machine , during these months , would be a reserve machine and be used in case of the other machine broke down.

For winter when the demand of current is great , say for about 3 months of each year , the 2-I,000 K.W. units would be in operation, over loaded for the peak load, and the one unit of I,ooo K.W. machine be reserve for case of emergency.

Exciter.

Mr. M. H. Hobart gives the following table for determination of the size of exciter.

Excitation Power Required for Alternators.

Rated Out - Put K. W.	Power Required for Excitation at Full Load							
	High Speed				Slow Speed			
	P.F = 1		P.F. = 0.8		P.F. = 1		P.F. = 0.8	
	K.W	%	K.W.	%	K.W.	%	K.W	%
500	2	0.4	3	0.6	5	1.0	7	1.40
1,000	5	0.5	7	0.7	7	0.7	10	1.00
2,000	9	0.45	13	0.65	11	0.55	15	0.75
4,000	13	0.33	18	0.45	16	0.4	22	0.55
8,000	16	0.2	22	0.28				

From this table the following capacities of exciters are determined.

2 Units , I5 K.W. , I25 volts . D.C. Generaters.

750 R.P.M.

One of unit is to be used in case of emergency. For their efficiencies , see plate no. 27 .

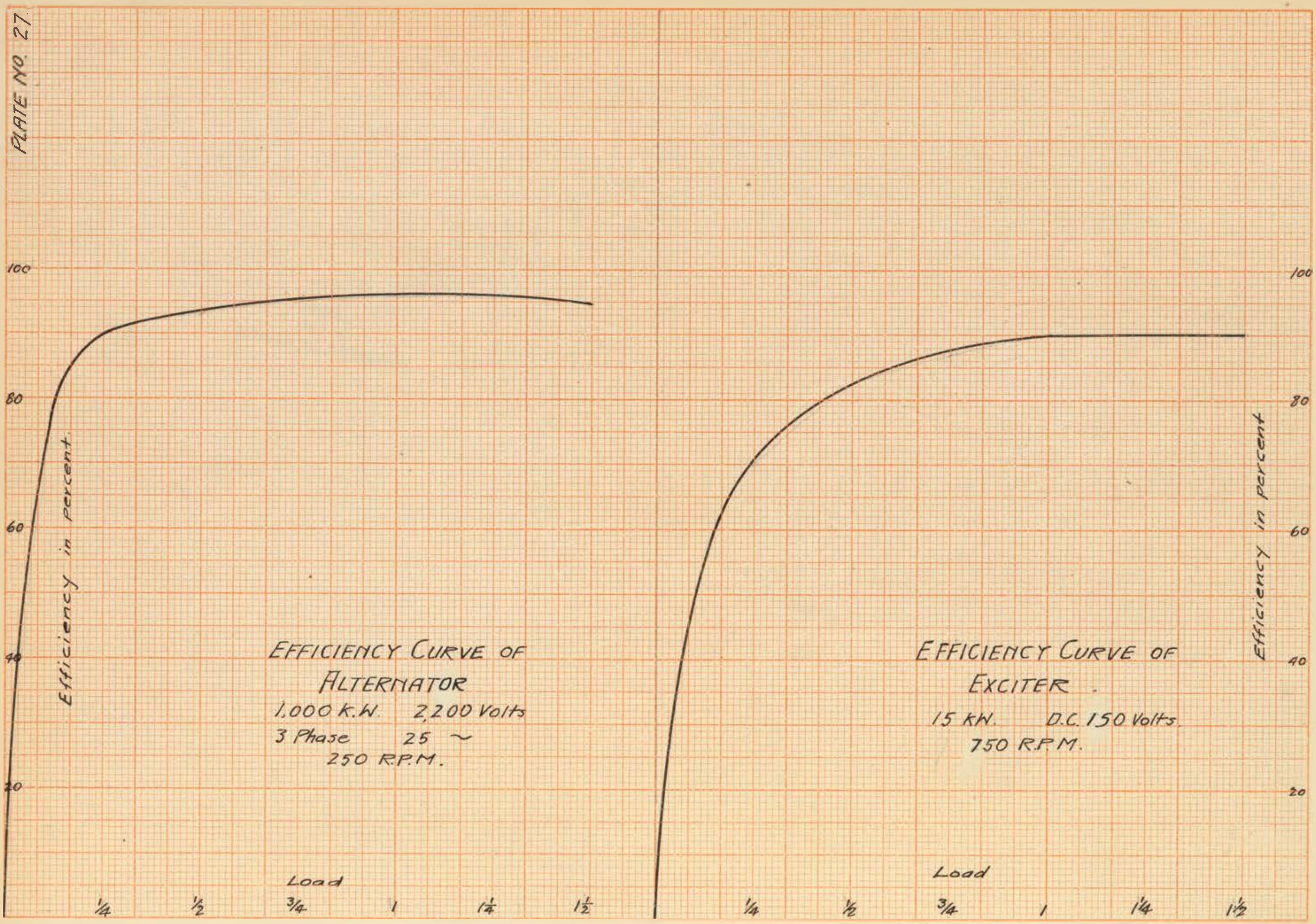


PLATE NO. 27.
100
80
60
40
20
Efficiency in percent
EFFICIENCY CURVE OF
ALTERNATOR
1,000 K.W. 2,200 Volts
3 Phase 25 ~
250 R.P.M.
Load
1/4
1/2
3/4
1
1 1/4
1 1/2
EFFICIENCY CURVE OF
EXCITER.
15 KW. D.C. 150 Volts.
750 R.P.M.
Load
1/4
1/2
3/4
1
1 1/4
1 1/2
Efficiency in percent
100
80
60
40
20

Switching and Controlling Apparatus.

The object of the switch board is to collect the generated current for the purpose of controlling, measuring and distributing the same.

In order to accomplish these purposes the following general features are considered for the selection of the switch board.

I The apparatus and supports should be fire proof.

2 The conductors and contacts carrying current must be designed so that they will not over heat.

3 Allparts should be readily accessible.

4 Live parts, except those of low potential, should be kept from the front of the operating panels.

5 The arrangement of the circuits should be symmetrical and as simple as it is convenient to make them.

6 As far as possible, without too great complication of apparatus, it should be impossible to make a wrong connection that will cause serious results.

7 If there is a liability of the plant being extended, allowance should be made for the extention of the switch board.

8 Trouble in one section of the board should not be communicated to the entire system.

9 All necessary instruments for operation and for recording the output of the generators and feeders should be installed.

IO Protective apparatus should be ample.

These features in mind , the design of switching for this plant is planned.

Switch Board.

The type used for this plant is the remote control panel type switch board. (Plate No. 28).

Apparatus Required.

A.C. Generator Panel :

I Alternating current ammeter. (with necessary transformers and plugs to connect one ammeter to any phase)

I Alternating current voltmeter. (a voltmeter plug receptacle and plugging arrangement to utilize one voltmeter with several machines.)

3 Main generator switches and circuit breakers.

3 Field discharge switches with resistances.

3 Rheostats for field of generators.

One set of apparatus for synchronizing , with necessary current and voltage transformers.

I Indicating wattmeter. (with plugging arrangement.)

Feeder Panel for Power Service.

Apparatus required for each circuit.

One ammeter .

One integrating wattmeter.

One automatic over load circuit-breaker.

Necessary current and potential transformers.

A.C. Totalizing Panel.

One integrating wattmeter (high tension.)

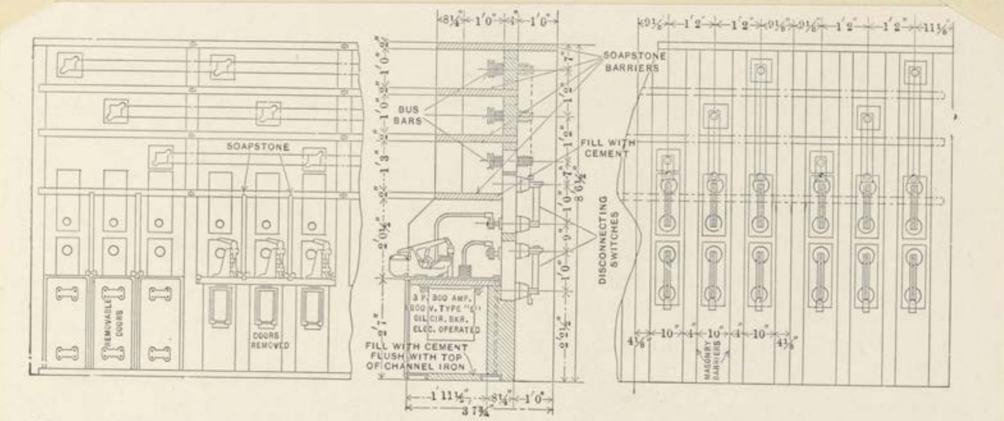
One " " (Low tension.)

One frequency meter.

One main voltmeter. (high tension.)

One " " (low tension.)

Necessary current and voltage transformers.



Front View of Structure

Rear View of Structure

Bus-Bar and Oil Switch Structure for 33,000 Volts Three-Phase Generating Plant

D.C. Excitor Panel.

One voltmeter.

Two direct current ammeters.

Two three pole main switches.

Two rheostats.

Lightning Protection.

A lightning arrester is a device for protecting against interruption of service and distruction of the generating plant, the line, and the other electrical apparatus by sudden excessive potential discharges. The excessive potential discharges may be due to the followings.

I Lightning striking the line

2 Any atomospheric, electric disturbance.

3 Static discharges.

4 Resonance effect.

5 Surging produced by abnormal conditions in the line.

6 Break in insulators.

Principle of arrester.

In general , a lightning arrester is made up of three elements;

I An air gap.

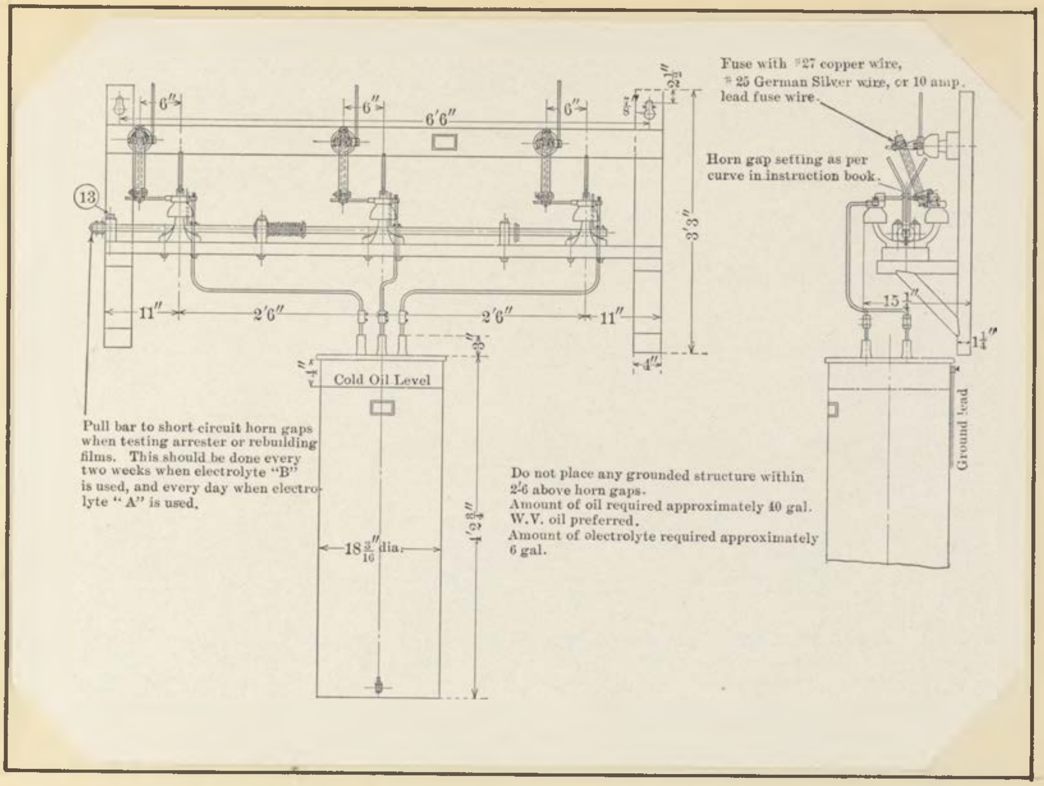
2 A current limiting element.

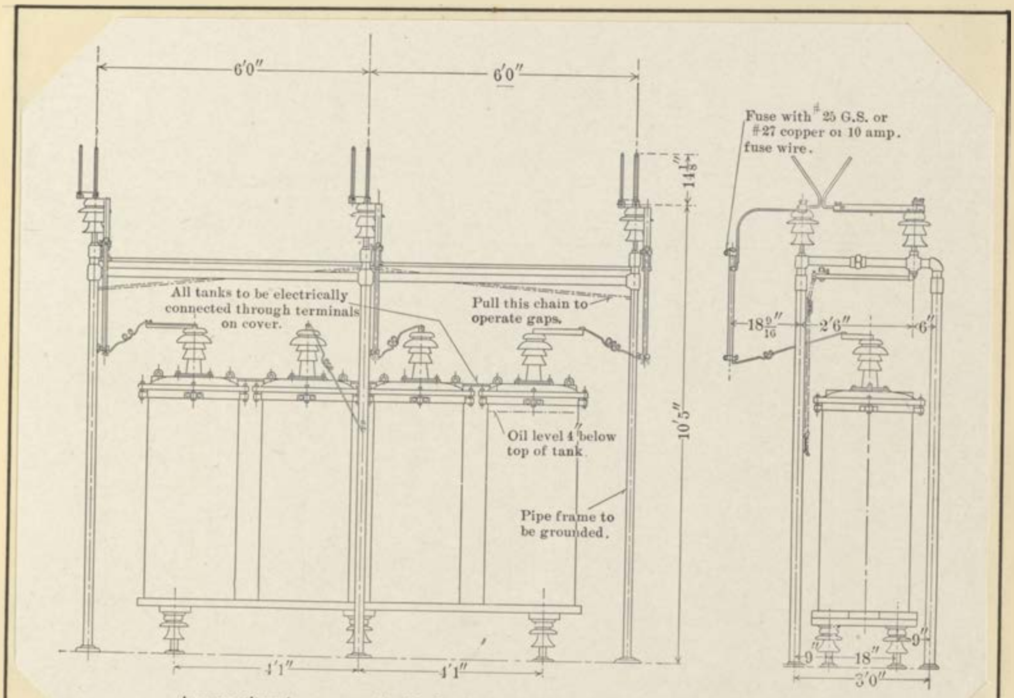
3 An arc suppressing device.

For this plant the electrolytic lightning arrester is chosen. The general appearances and dimensions are shown on the plate Nos.29 & 30.

For main high tension lines:-

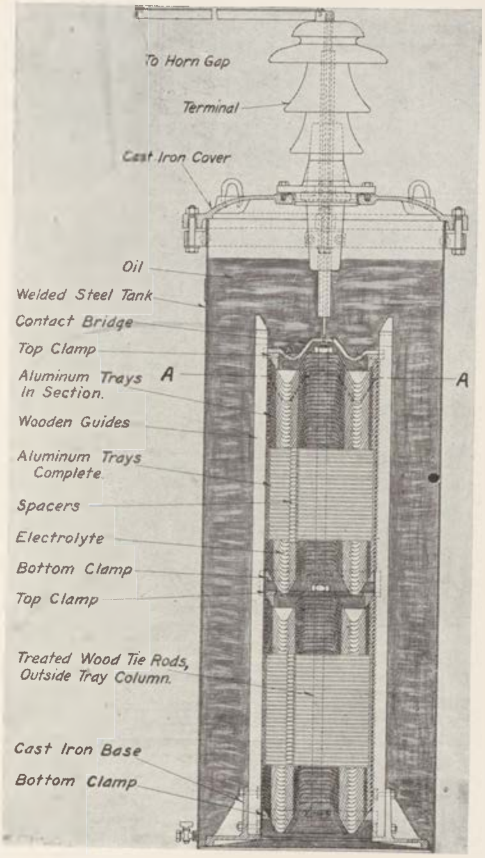
Two 3 phase A.C. 33,000 volts arresters.

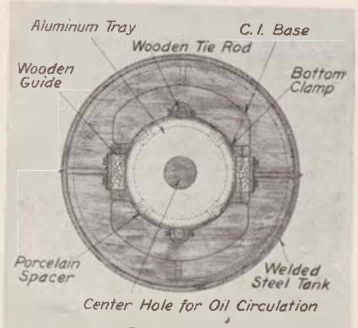




Approximate amount of electrolyte required, 32 gals.
Approximate amount of oil (W. V. oil preferred) required, 360 gals.

LIGHTNING ARRESTER





SECTION A–A

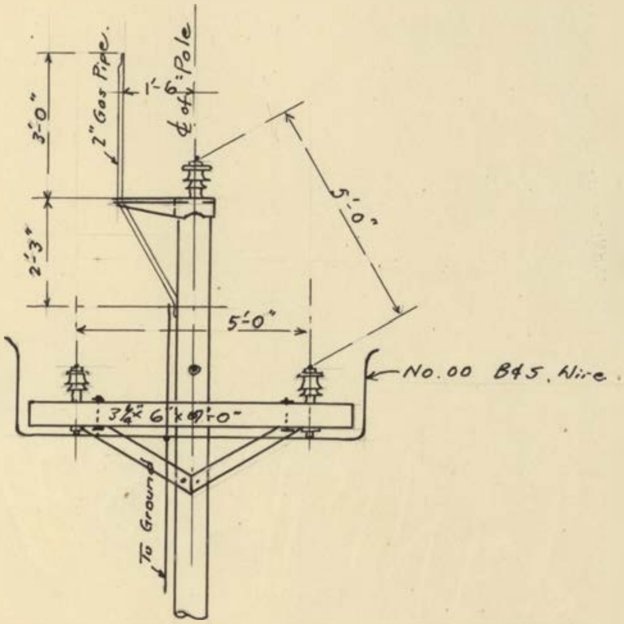
CROSS-SECTIONAL VIEW OF LIGHTNING ARRESTER

For low tension line :-

One 3 phase A.C. 6,600 volts arrester.

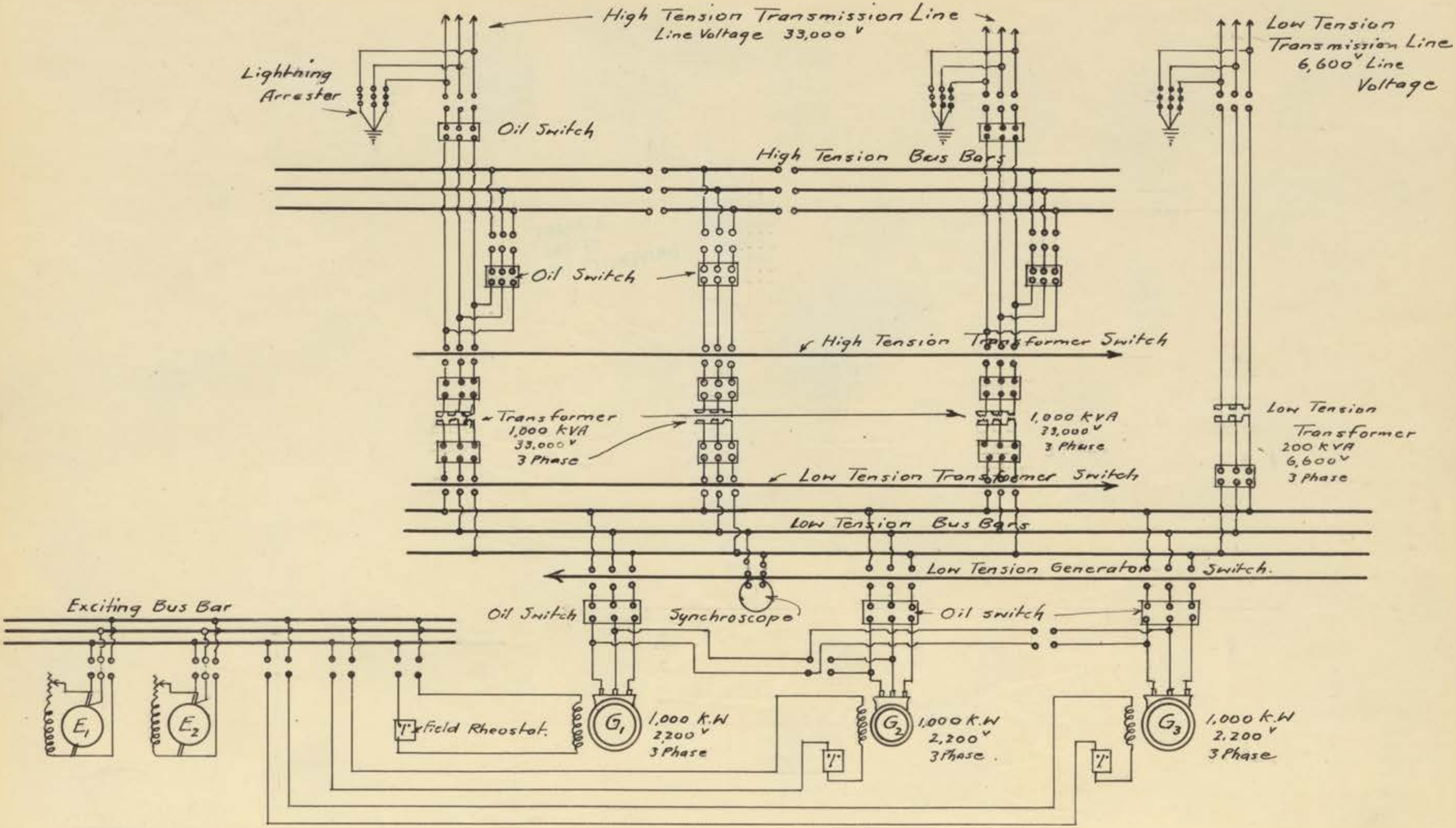
For D.C. excitors ; two I50 volts arresters.

For the transmission line lightning rod is placed every two miles. Its dimension is shown as below.



Arrangement of Lightning Rod.

The general arrangement of the station wiring is shown diagrammatically on plate no. 3I.



WIRING DIAGRAM OF THE WHITE SALMON RIVER POWER PLANT.

PART 5 .

Mechanical Equipment.

Turbines.

General requirements for turbines.

Before the turbine units can be determined the following requirements for a good water turbine must be considered.

I Turbine should occupy a small space.

2 It should be connected to the generator without gearing and with a consequent saving in power.

3 Its efficiency should be high.

4 Should permit variation in speed without material change in efficiency.

5 It should be utilized under any head or fall of water.

6 It should be readily protected from ice interference.

Determination of Units.

The water wheel as a rule , is rated at its maximum output, therefore in order to drive the generator at over load, the capacity of turbine is chosen 20 to 25 percent greater than the power required to drive its dynamo .

Therefore in this plant , we require the following sizes of turbines:-

3- Units I676 H.P. 250 R.P.M.

2- Units 25 H.P. 750 R.P.M. (for excitors).

Relation of speed to diameter and head.

We have found the required power of turbines . And the speed of the turbines are given , which are fixed by the generator's rotation. There are several water wheel factories in the United States and each factory , wheel is only suited for a particular head, power, and speed.

Professor D.W. Mead made a table showing relation of speed and power of various American turbines working under catalogue conditions. By means of his table , we may easily select the best wheel in this particular plant. In order to apply his table , we must find out a constant K, which is drived as below:-

$$K = \frac{n^2 P}{h^{\frac{5}{2}}}$$

K = Coefficient of relation of turbine power and speed (specific speed)

n = Number revolution per minute .

P = Horse powers of turbine at any given head.

h = Effective head at the wheel.

Applying our given values in this equation;

For generator turbine

$$K = \frac{\overline{250}^2 \times 1676}{120^{5/2}} = 605$$

e

For exciter turbine

$$K = \frac{\overline{750}^2 \times 25}{120^{5/2}} = 89.5$$

Having the value of K , from the table , it is found that the Dayton Grove Iron Work's , New America (high speed type) wheel has practically this value of K of 1676 H.P. unit. For excitor's turbine the Plat Water Wheel Co's wheel (Victor Francis type) has a close value of the K. Therefore these wheels are selected for this particular service.

Determination of the diameter of wheel.

From prof. Mead's table K_2(constant relation of turbine diameter to power) for the Dayton Globe wheel is found to be

0.0005 , and for the Plat Water Wheel Co's wheel K_2 is about 0.0002. Then the relation of turbine diameter to power may be expressed as below ;

$$D = \sqrt{\frac{P}{K_2\, h^{3/2}}}$$

D = Diameter of turbine in inches

Substituting the value in this equation;

For 1676 H.P. turbine ,

$$D = \sqrt{\frac{1676}{0.0005 \times 120^{3/2}}} = 49.3 \text{ inches.}$$

Consulting the catalogue 48 inches diameter is selected.

For 25 H.P. turbine

$$D = \sqrt{\frac{25}{0.0002 \times 1320}} = 9.75 \text{ inches}$$

A diameter of 10 inches is selected for this unit .

Draft tubes.

The turbines are equiped with draft tubes in order to secure additional head, which would otherwise be lost .

The length of draft tubes are constructed within the limit of following table . (the actual length of the draft tubes used for this plant may be seen on plate no. 43.)

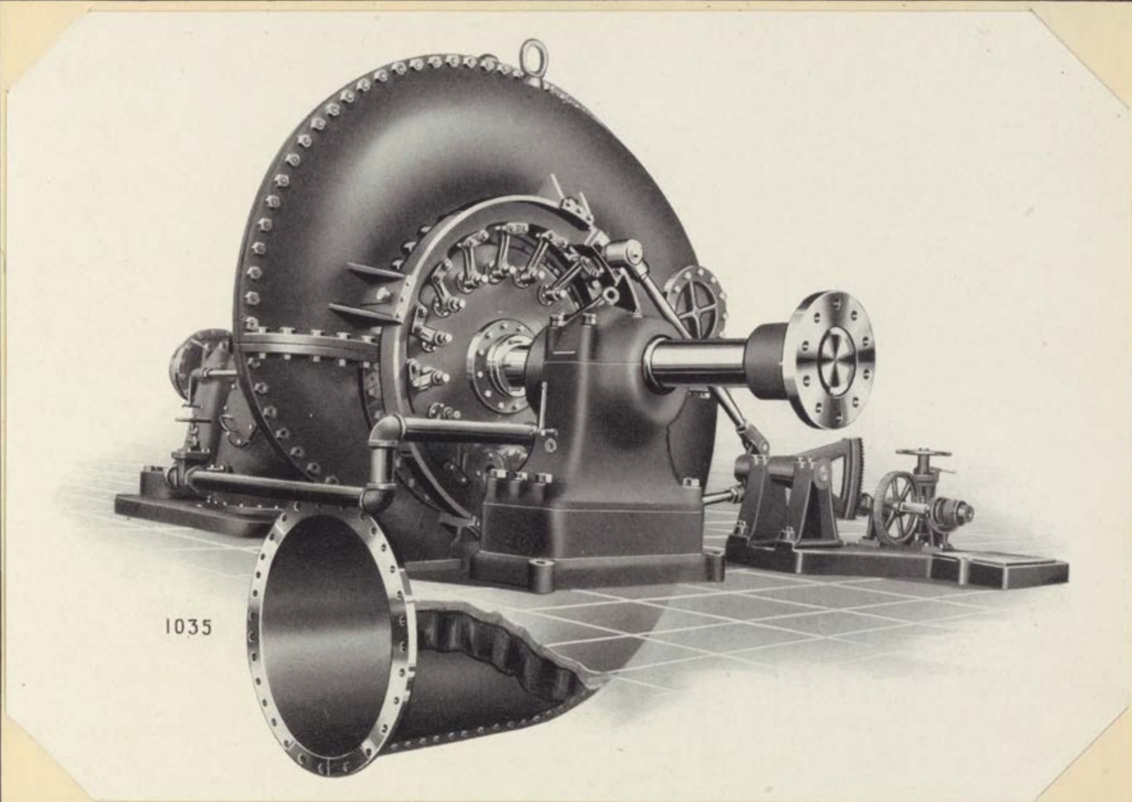
Hight of Draft Tubes and its relation to Heads. (Meissuer, Hydrauliche Motorn.)

Diameter of Draft in feet	Draft Head in feet	Diameter of Draft in feet	Draft Head in ft.
3	24.0	5	19.0
4	21.0	6	17.0

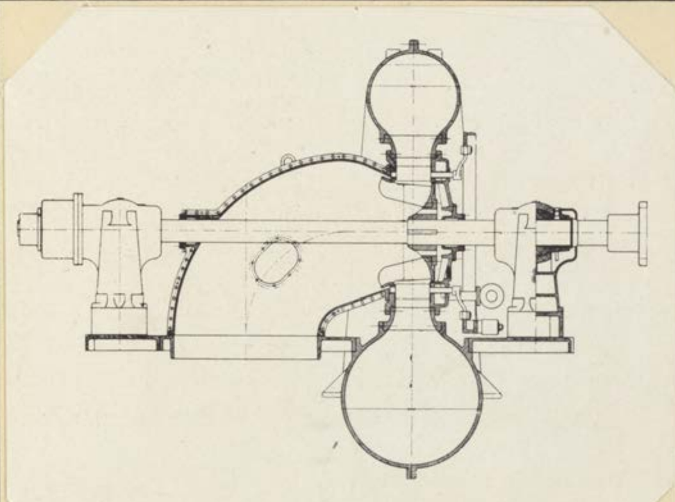
Regulation Device.

A Lombord Governer is connected to the penstock near the turbine, and can be set for any excess pressure desired. This governor consists essentially of three parts :- The oil pump, the pressure and vacum tanks, and governing mechanism. (See, Plate No. 42 .)

The Dayton Globe Iron Work's High Speed Type " New America " Turbine is shown on plate no. 37.



THE DAYTON GLOVE WATER WHEEL
1676 H.P. 250. R.P.M. 48 INCH DIAM. WHEEL.



Sectional View of Above Turbine

PART 6.

Water Conductor .

General Consideration.

In the design of the water conductor the following points are considered;

I Method of regulating the water supply.

2 Methd of conducting the water to and from the power station.

3 The removal from the water supply of injurious floating and suspended matter.

4 The means of controlling the water supply to the penstocks or other forms of intake.

Penstocks.

The steel penstocks are connected to the flume line and their intake of water regulated by means of the autmatic cup valve at their upper ends. (See , Plate No. 34.)
From the intake the penstocks run parallel to each other down to the power plant and are connected to their turbines.
Each penstock is interconnected at the power plant, with properly equipped valves, so that in case of emergency, the water of one penstock may feed other turbines.

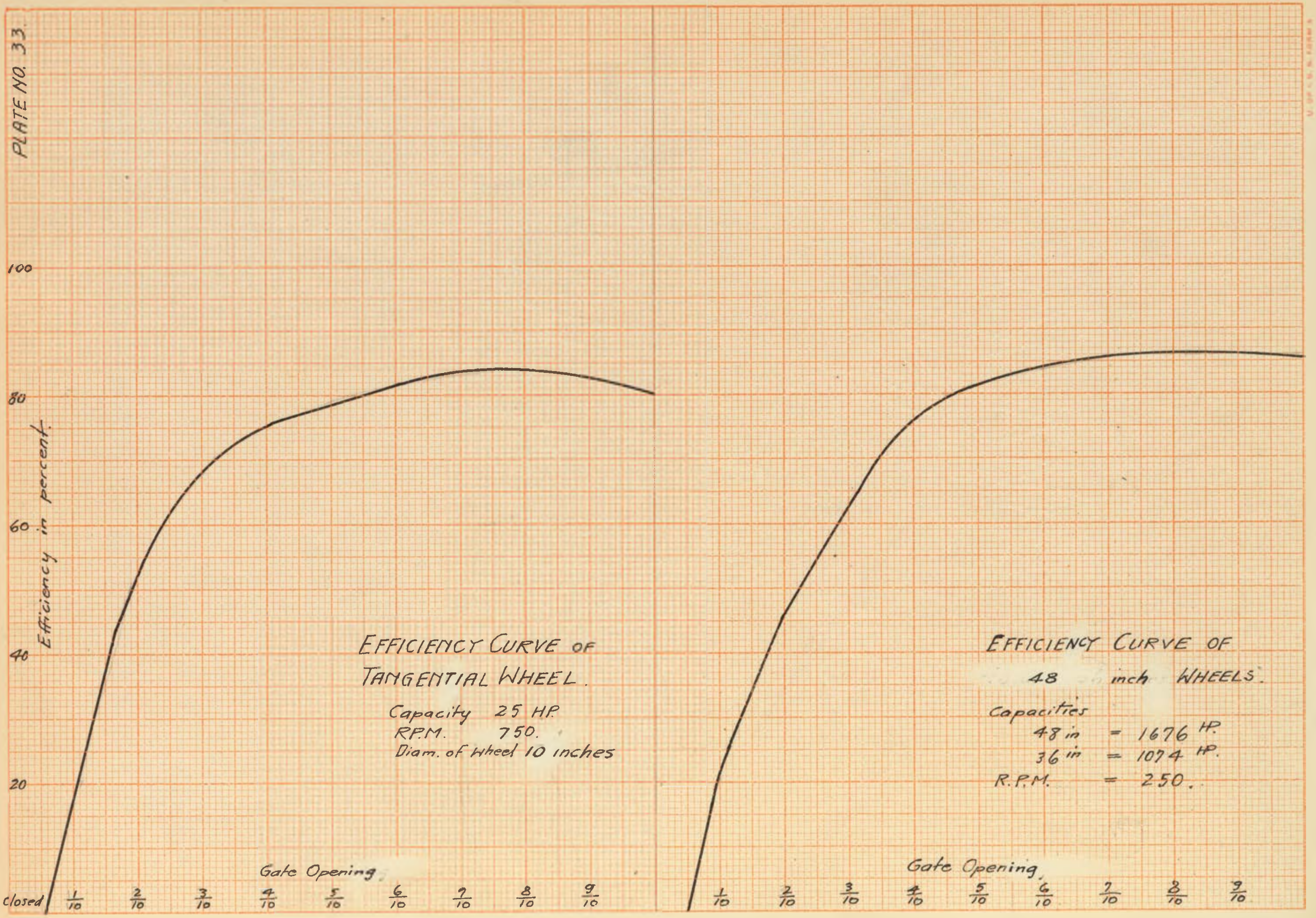
Calculation of the losses in penstocks.

Penstocks for the 48 in. dia. turbine.

Quantity of water required to produce I676 H.P. on the turbine(See, page 48.) , and from the efficiency curve of the turbine (Plate No. 33 .) , we have its efficiency at full load as 84 % , but calls it 80 % , and Assuming the effective head as I20 feet, then

If let, Q = Discharge of water of the turbine cub. ft./ sec .

PLATE NO. 33


100
80
60
40
20
Efficiency in percent.
closed
1/10
2/10
3/10
4/10
5/10
6/10
7/10
8/10
9/10
Gate Opening
EFFICIENCY CURVE OF
TANGENTIAL WHEEL.
Capacity 25 HP.
R.P.M. 750.
Diam. of Wheel 10 inches
EFFICIENCY CURVE OF
48 inch WHEELS.
Capacities
48 in = 1676 HP.
36 in = 1074 HP.
R.P.M. = 250.
Gate Opening
1/10
2/10
3/10
4/10
5/10
6/10
7/10
8/10
9/10

$$Q = \frac{1676 \times 550}{0.8 \times 62.5 \times 120} = 153.6 \text{ cubic feet per second}$$

Since

$$V = \frac{Q}{a} , \quad Q = V a$$

Where; V = Velocity in ft. sec.

a = Area in square ft.

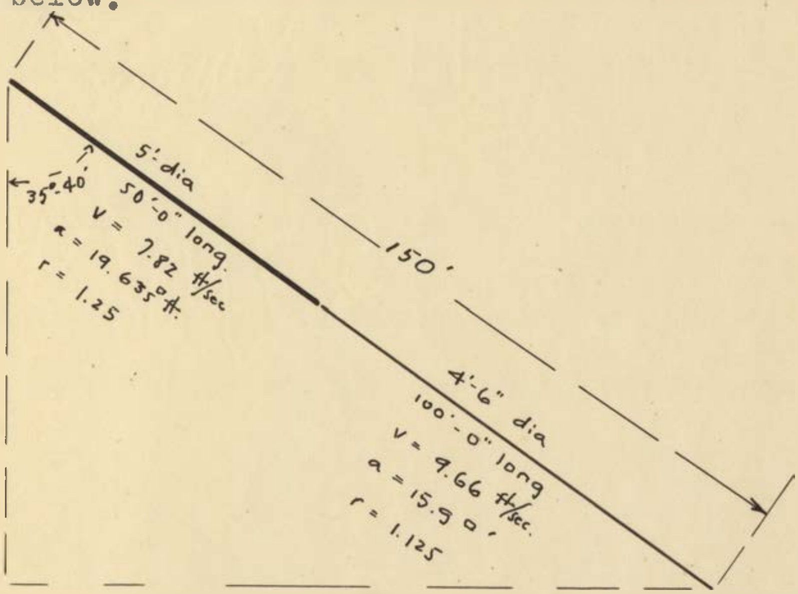
Assuming the velocity in the lower part of the penstocks as 10 feet per second, then the required area of the penstock ;

$$a = 153.6 / 10 = 15.36 \text{ sq. ft.}$$

Therefore 4 feet 6 inches pipe is used , then , the velocity will be 9.66 feet per second in this cross section.

By the same procedure , the upper part of the penstock is found to be 5 feet diameter, and its velocity is 7.82 ft./ sec.

The necessary data for the calculation for the loss is tabulated below.



The losses are:-

I Entrance loss

$$h' = .956 \frac{v^2}{2g} = .956 \frac{\overline{7.82}^2}{32 \times 2} = 0.908 \text{ ft.}$$

2 Loss of head in straight pipe.

$$h' = \frac{1 \quad V^2}{10000\ r} ;$$

For 5 feet dia. pipe;

$$\frac{50 \times \overline{7.82}^2}{10000 \times 1.125} = 0.242 \text{ feet}$$

For 4 feet 6 inches pipe;

$$\frac{100 \times \overline{9.66}^2}{10000 \times 1.125} = 0.828 \text{ feet}$$

3 Loss of head due to sudden contraction of pipe.

$$h' = K \frac{V^2}{2g} = 0.015 \frac{7.82}{64.4} = 0.0142 \text{ feet}$$

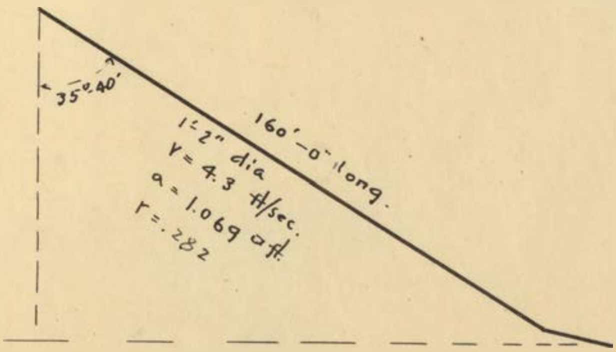
Total losses , therefore

$$0.908 + 0.242 + 0.828 + 0.014 = 1.992 \text{ feet.}$$

The quantity of water required for 10 inch exciter wheels are calculated below, where in these wheels one size of penstock is used.

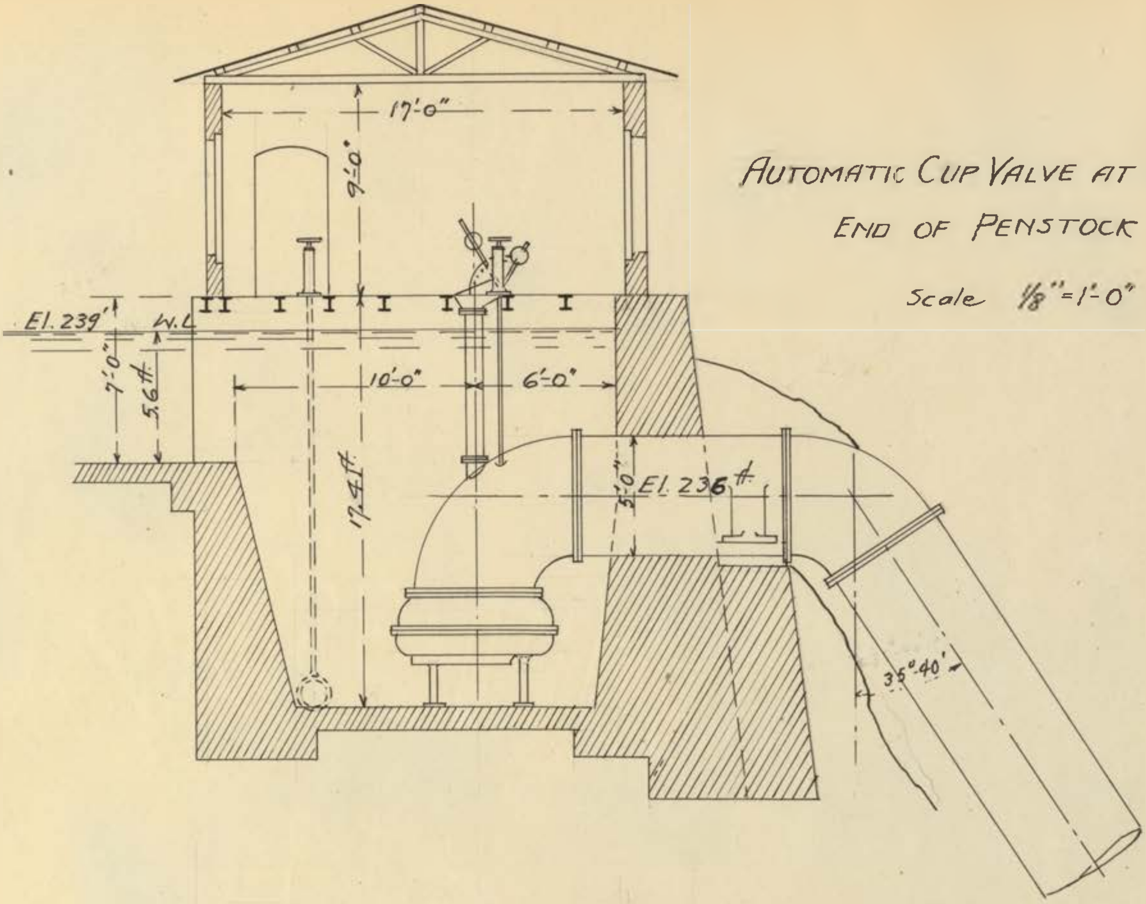
$$Q = \frac{50 \times 550}{.8 \times 62.5 \times 120} = 4.6 \text{ cubic feet per second.}$$

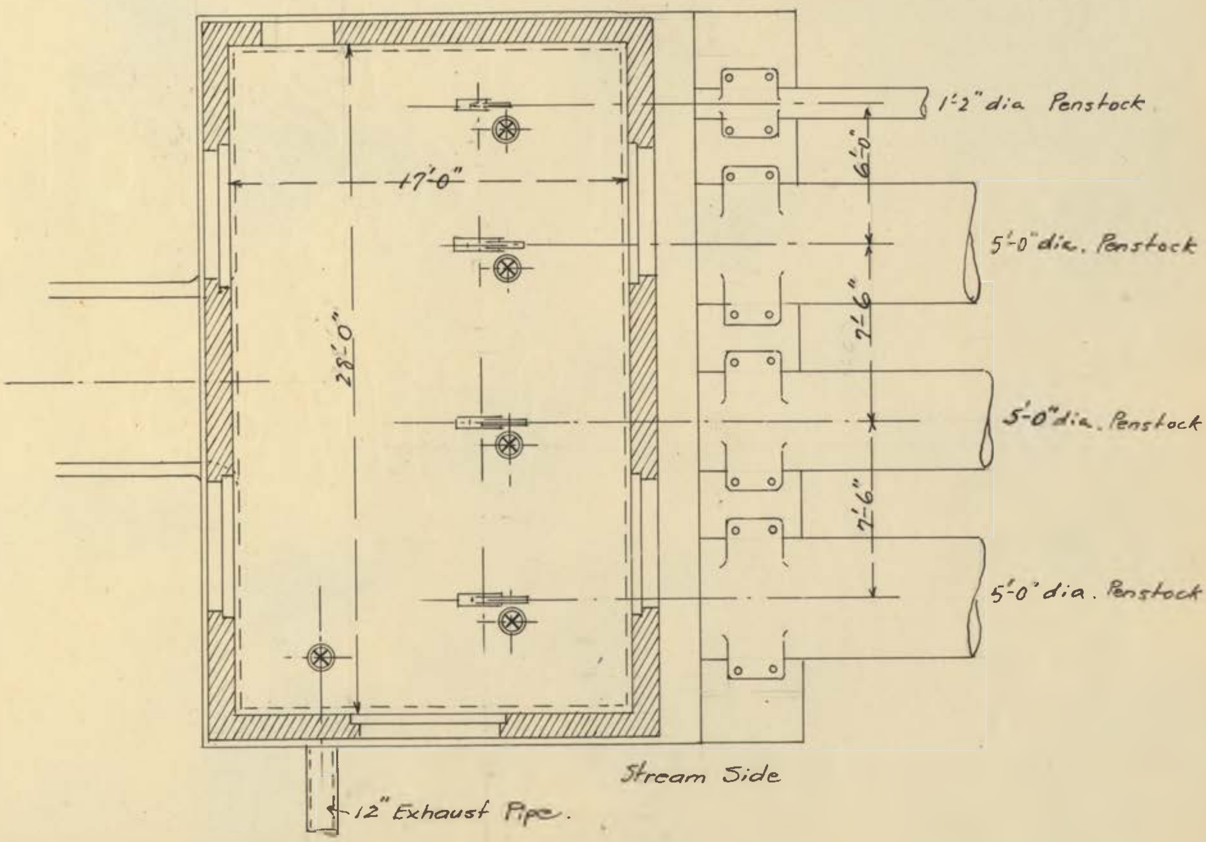
The result of determined diameter of pipe and the velocity and its hydraulic radius is shown diagrammatically as below.



AUTOMATIC CUP VALVE AT UPPER END OF PENSTOCK.

Scale 1/8" = 1'-0"





The loss of the head is.

I Pipe line loss.

$$h' = \frac{160 \times \overline{4.3}^2}{10000 \times 0.282} = 1.05 \text{ feet}$$

2 Entrance loss

$$h' = 0.956 \times \frac{\overline{4.3}^2}{64.4} = 0.275 \text{ feet.}$$

Total head losses is $1.05 + 0.275 = 1.325$ feet.

The arrangement of the penstocks at their intake and at the power plant will be seen on plate nos. 34 & 43 .

The intake of the penstocks.

The intakes of the penstocks is located right above the power plant and are equipped with automatic regulating device for water supply to the penstocks and also an exhaust valve for waste water.

In order to compensate the lost head due to flood , an allowance of a loss of 3 feet is provided at the tank of this intake. (See, Plate No. 34.)

Strength of the penstocks.

In calculating the thickness of the penstock shell , the following formula is used:-

t = thickness of shell in inches.

P = pressure in pound per square inch.

r = interdiameter in radius in inches.

T = tensile strength = 60,000 lbs./ sq. in.

s = factor of safety = 4

P' = allowance for water hammer in pound per square inch.

$$t = \frac{(P + P')r\ s}{T}$$

The calculated data and selected dimensions are tabulated as below ;

Diameter	r	P	P′	Head	Total Pressure	Thickness	Thickness	actually used thickness inch
5′-0″	30	18.1	70	41.6	88.1	.1762	11/64	1/4″
4′-6″	27	53.7	70	123.8	123.7	.223	15/64	3/8″
1′-2″	7	53.7	110	123.8	163.7	.1525	5/32	3/16″

Flume.

A wooden flume is chosen , owing to its cheapness in first cost , simplicity in construction, and future extention of the same.

The quantity of water which is to pass through the flume is designed to operate the two I,000 K.W. generators at their 25 % over loaded conditions , that is , to drive the fullload capacities 2- I,676 H.P. water turbines. The quantity of water to be carried by the flume is ;

For I' 2" penstocks 4.6 cub.ft. per sec.

For 5' 0" penstocks 2 x I53.6 = 307.2 cub.ft. per sec.

Total quantity = 3II.8 cubic feet per second.

Determination of the cross section of the flume.

Given items.

Total length of the flume line = 9,200 feet

Slope = I ft. per I,000 feet.

Let assume the velocity is 8 feet per second.

Area = 3II.8 / 8 = 39 sq. ft.

Assuming again a cross section of the flume as

$$7 \times 5.6 = 39 \text{ sq. ft.}$$

Let p = wetted perimeter

r = hydraulic radius

In this case, $p = 7 + 11.2 = 18.2$ ft.

$r = 2.155$; $n = 0.01$.

From Kutter's formula, coefficient c is found to be 172

$$V = 172\sqrt{2.155 \times 0.001} = 8 \text{ ft. per second.}$$

Therefore the assumption is correct, and the above dimensions are to be used. The detail of the flume construction is shown plate no. 35.

Head gate.

The head gate is located, so as to overcome the flood water, the location is indicated on plate no. 15.

Racks are placed at the entrance of headrace, in order to keep the heavy floating material out. The racks are made of 3.5 by 0.5 inches bars, bolted together with separators.

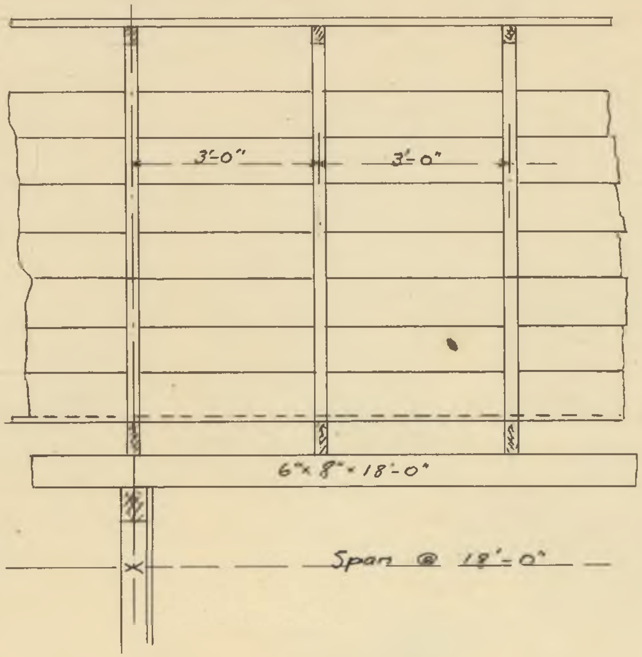
At the end of the open channel a spillway is provided so as to discharge the waste water directry into the stream. The detail of the construction is shown on plate nos. 36 & 37.

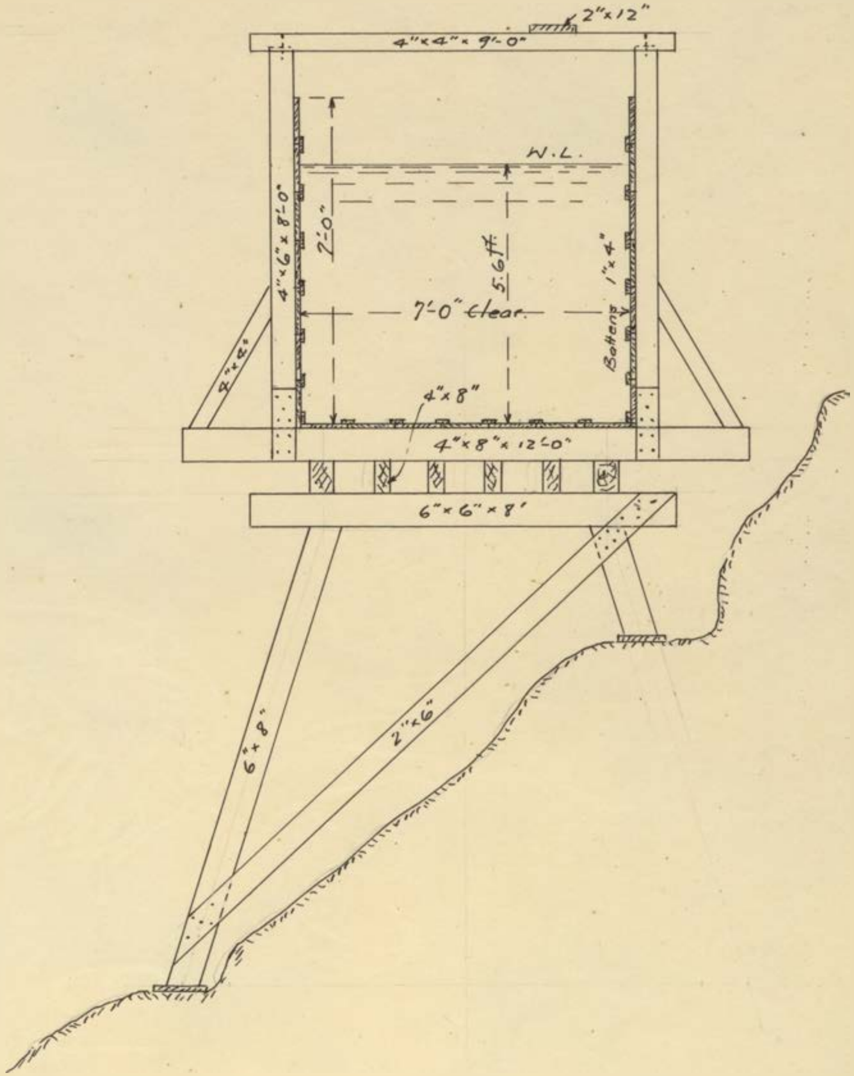
Open Channel.

A 2,100 feet long open channel is constructed from the dam inlet to the head gate.

As seen from the hydrograph (See, Plate No. 17.), there is ample water in this stream, therefore, an extension of the plant in the near future may be anticipated, with increase of power demand at the markets. For this reason, the open channel is excavated, so that 3- 1,000 K.W. generators can

PLATE NO. 35



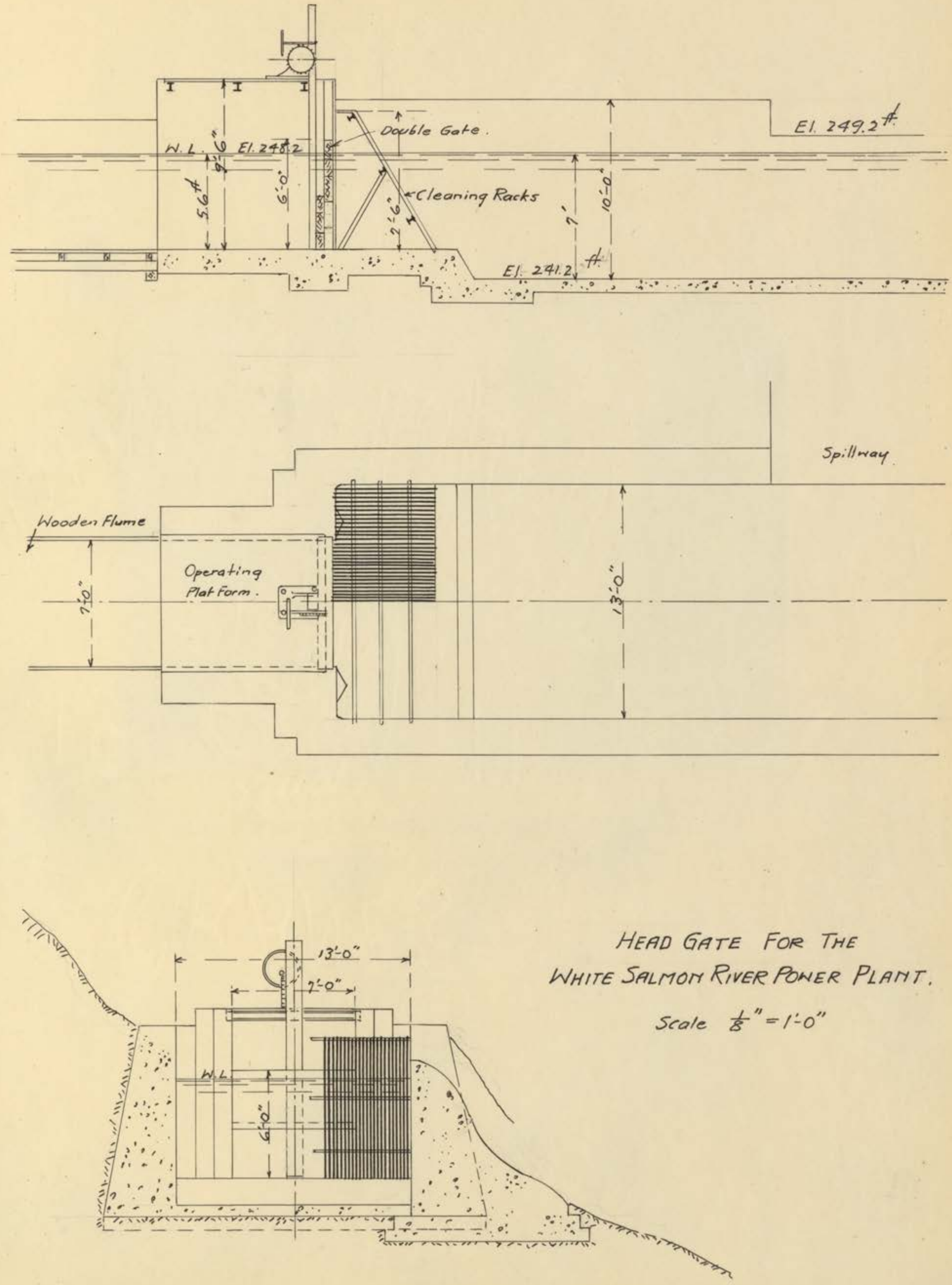


To carry 312 cub. ft. per sec. on a grade of 1 ft. in 1,000 ft.

Scale $\frac{1}{4}$" = 1'-0"

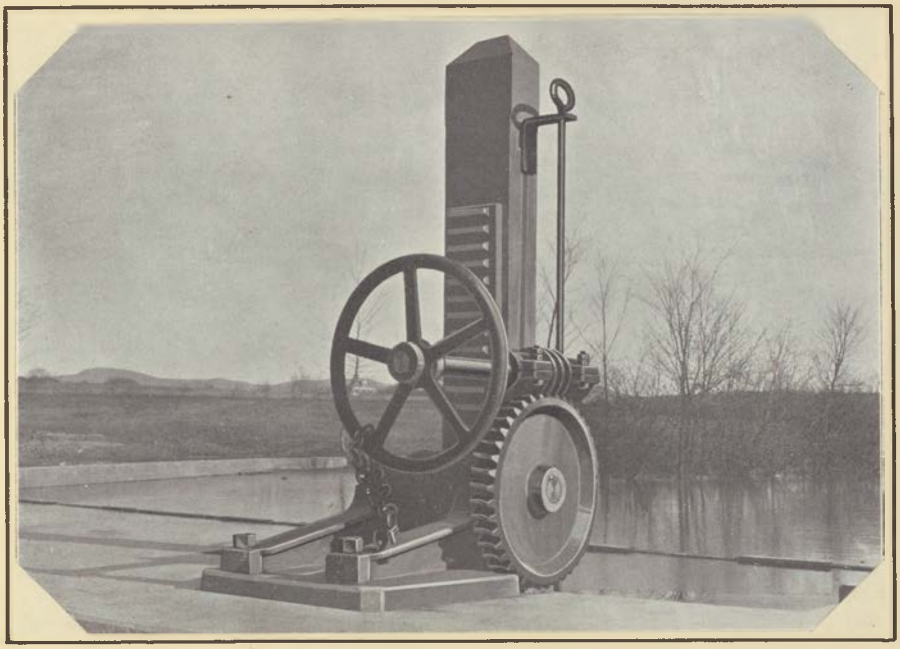
WOODEN FLUME FOR

THE WHITE SALMON RIVER POWER PLANT.



HEAD GATE FOR THE WHITE SALMON RIVER POWER PLANT.

Scale $\frac{1}{8}$" = 1'-0"



THE OPERATING DEVICE
FOR THE HEAD GATE

be operated under 25 % over loaded conditions.

Then the quantity of water to be carried by the channel

$$Q = 312 + 153.6 = 466. \text{ cub. ft. per second.}$$

The slope of the channel is I foot per I,000 feet.

A coefficient of n for rock channel is assumed 0.02 .

Assume the velocity as 5.I2 ft. per second.

The sectional area of the channel is then

$$a = \frac{466}{5.12} = 91 \text{ sq. ft.}$$

The section is assumed as $7' \times 13'$, then the hydraulic radius for this section is found to be 3.37, and Kutter's coefficient c is 89.9 .

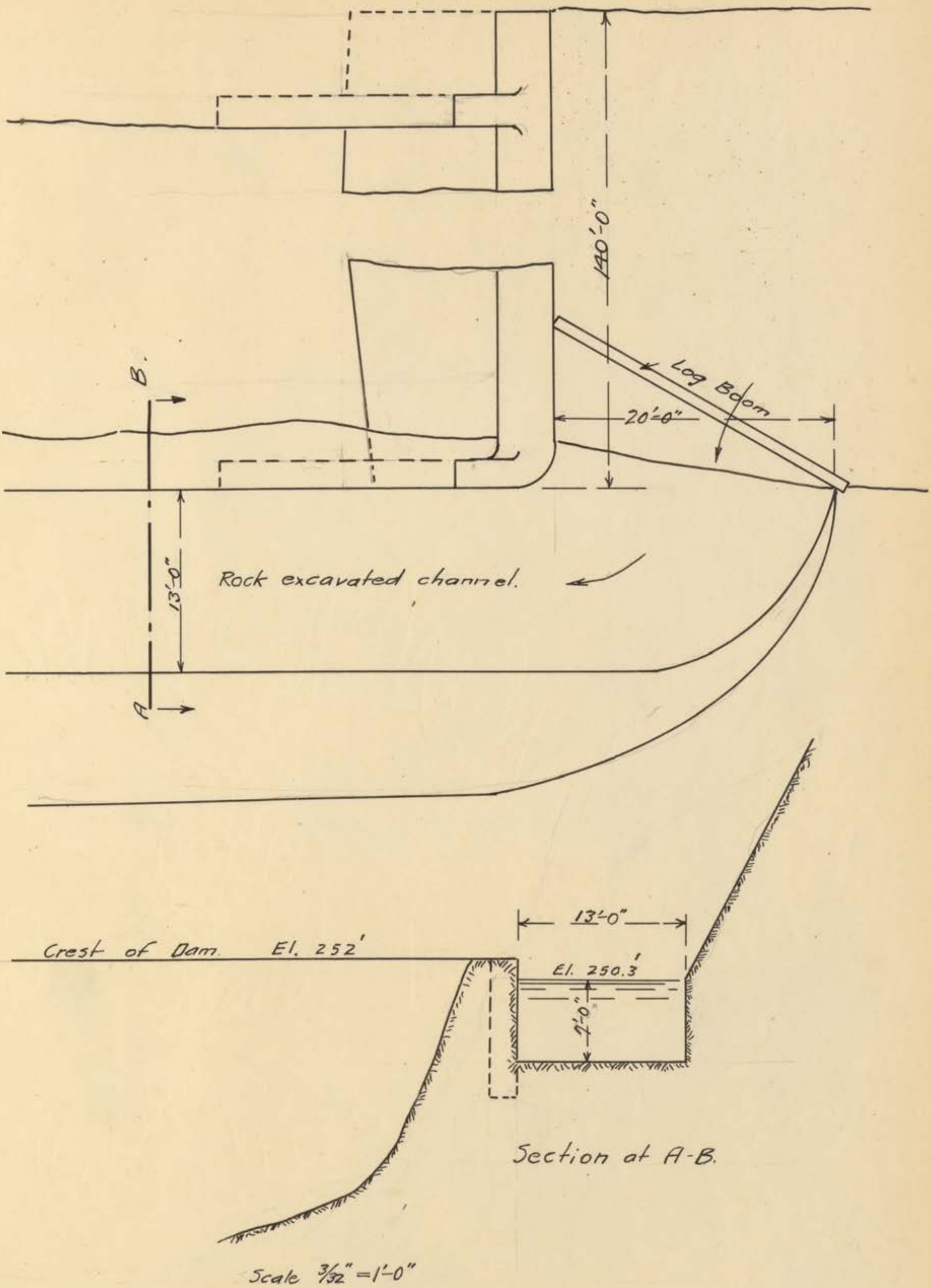
$$V = 89.9 \sqrt{3.37 \times 0.001} = 5.2 \text{ ft./ sec.}$$

Therefore the assumption is close enough. The dam inlet and the cross section of channel is shown on plate no.38.

Hydraulic Gradient.

In order to show the loss head due to the hydraulic development, a hydraulic gradient is drawn on plate no.39.

From this graph the general scheme of the arrangement of the water conductors will also be seen.



INLET AT THE DAM.

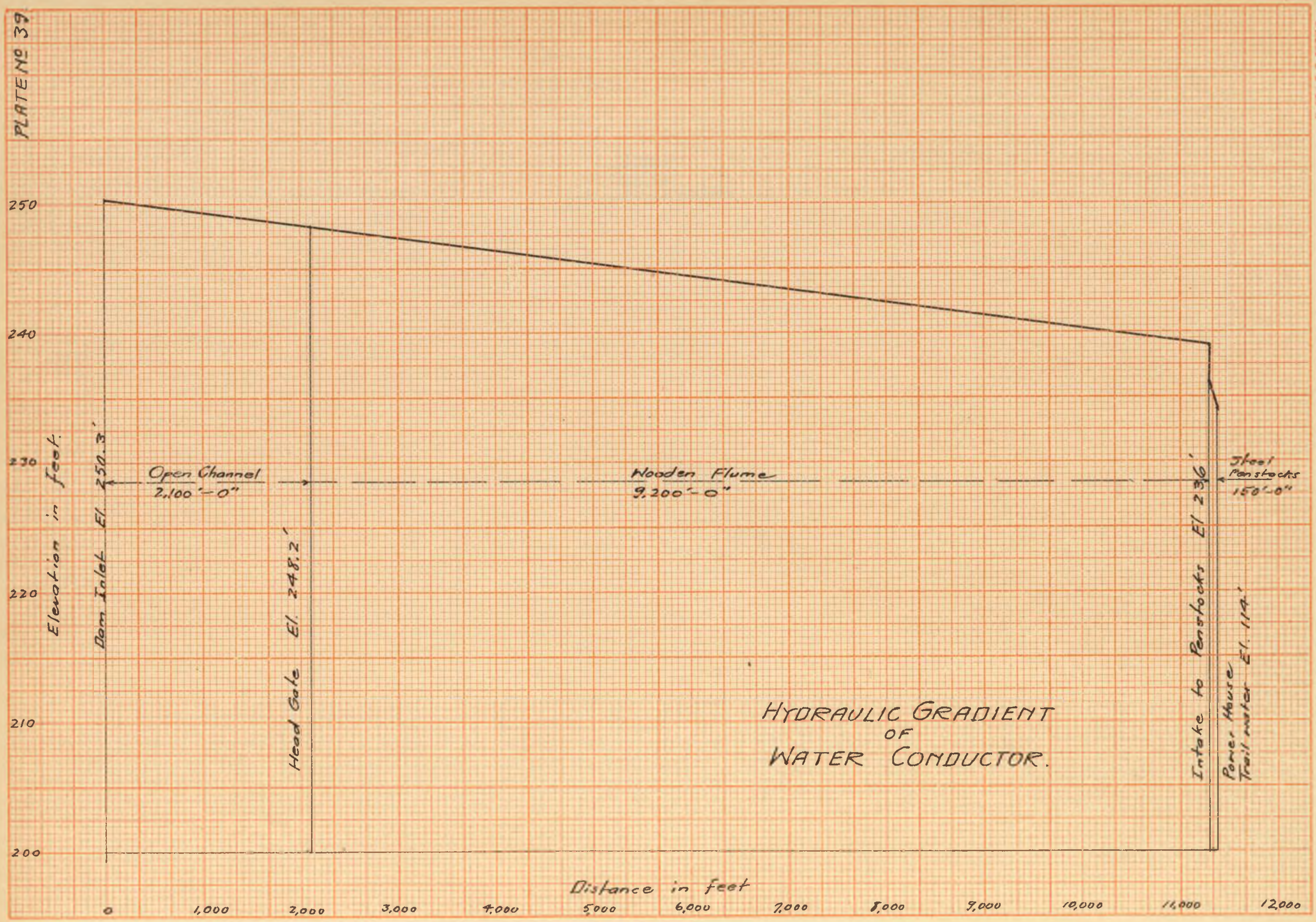


PLATE No 39
250
240
230
220
210
200
Elevation in Feet
Dam Inlet El. 250.3'
Head Gate El. 248.2'
Open Channel
2,100'-0"
Wooden Flume
9,200'-0"
Steel Penstocks
150'-0"
Intake to Penstocks El. 236'
Power House Tail water El. 114'
HYDRAULIC GRADIENT
OF
WATER CONDUCTOR.
Distance in feet
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000

PART 7

Dam .

Object of dam construction.

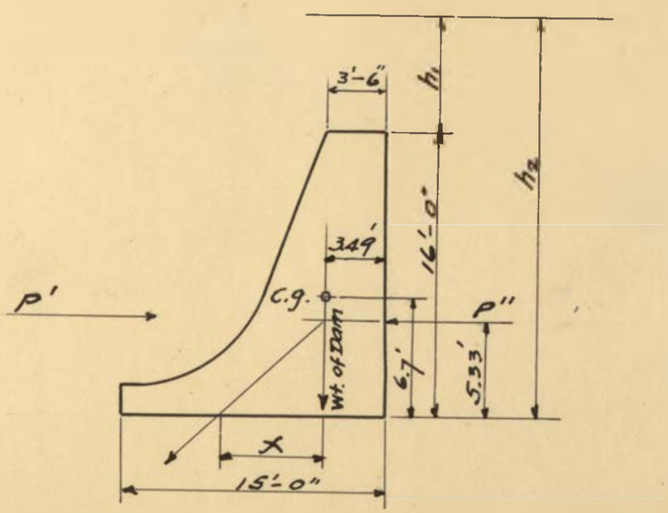
The dam is constructed with the object of obstructing the flow and elevating the surface of water.

The dam construction.

It is decided to built a gravity dam using mass concrete, because of the cheapness of material and ease of building. The external forces acting on a masonry dam are the water pressure , the weight masonry , the reaction of the foundation, ice and wave pressure near the top, wind pressure, and back pressure of the water on the down stream side. It, however, in this dam receives the greatest strain when it is submerged under the flood water. From the cross section of the site of dam and the discharge curve at that section the expected hight of over flow above the crest of dam is determined. (SEE, Plate No. 40.) And the stability of the dam under this condition is calculated as below.

Stability against over turning.

The location of the dam site is indicated on plate no. 15.



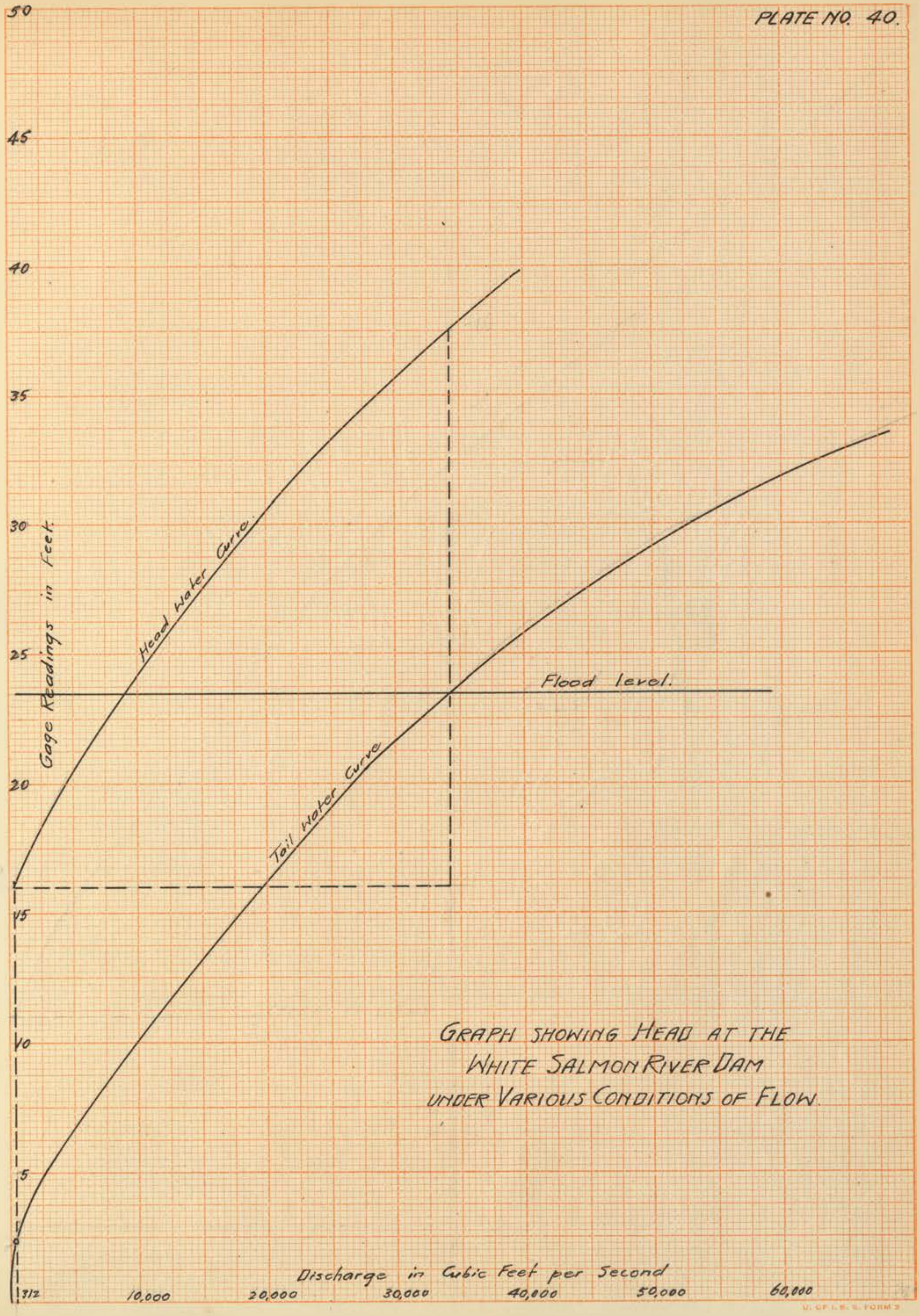
From the calculation and design of the water conductor, We have found that the hight of dam should be erected I6 feet.

Let ,

P = total pressure

P′ = back water pressure.

P″ = Front water pressure.


50
45
40
35
30
25
20
15
10
5
0
Gage Readings in Feet
Head Water Curve
Tail Water Curve
Flood level.
GRAPH SHOWING HEAD AT THE
WHITE SALMON RIVER DAM
UNDER VARIOUS CONDITIONS OF FLOW.
Discharge in Cubic Feet per Second
312
10,000
20,000
30,000
40,000
50,000
60,000

w = weight of water per cub. ft.

Then ; $P = P'' - p'$

Where

$$P' = \frac{w\,(h_2 - h_1)^2}{2} = \frac{62.5 \times \overline{16}^2}{2} = 8{,}000 \text{ lbs.}$$

$$P'' = \frac{w\,h_1 + w\,h_2}{2}(h_2 - h_1) = \frac{62.5 \times (21.6 + 37.6}{2} \times 16$$

$$= 29{,}600 \text{ lbs.}$$

$$P = 29{,}600 - 8{,}000 = 21{,}600 \text{ lbs.}$$

The cross section of dam is assumed , from which the weight of dam is found.

$$118.55 \times 150 = 17{,}800 \text{ lbs per ft.}$$

Let , X = distance where resultant forces acting from the vertical line of center of gravity.

$$21{,}600 :: 17{,}800 = X :: 16/3$$

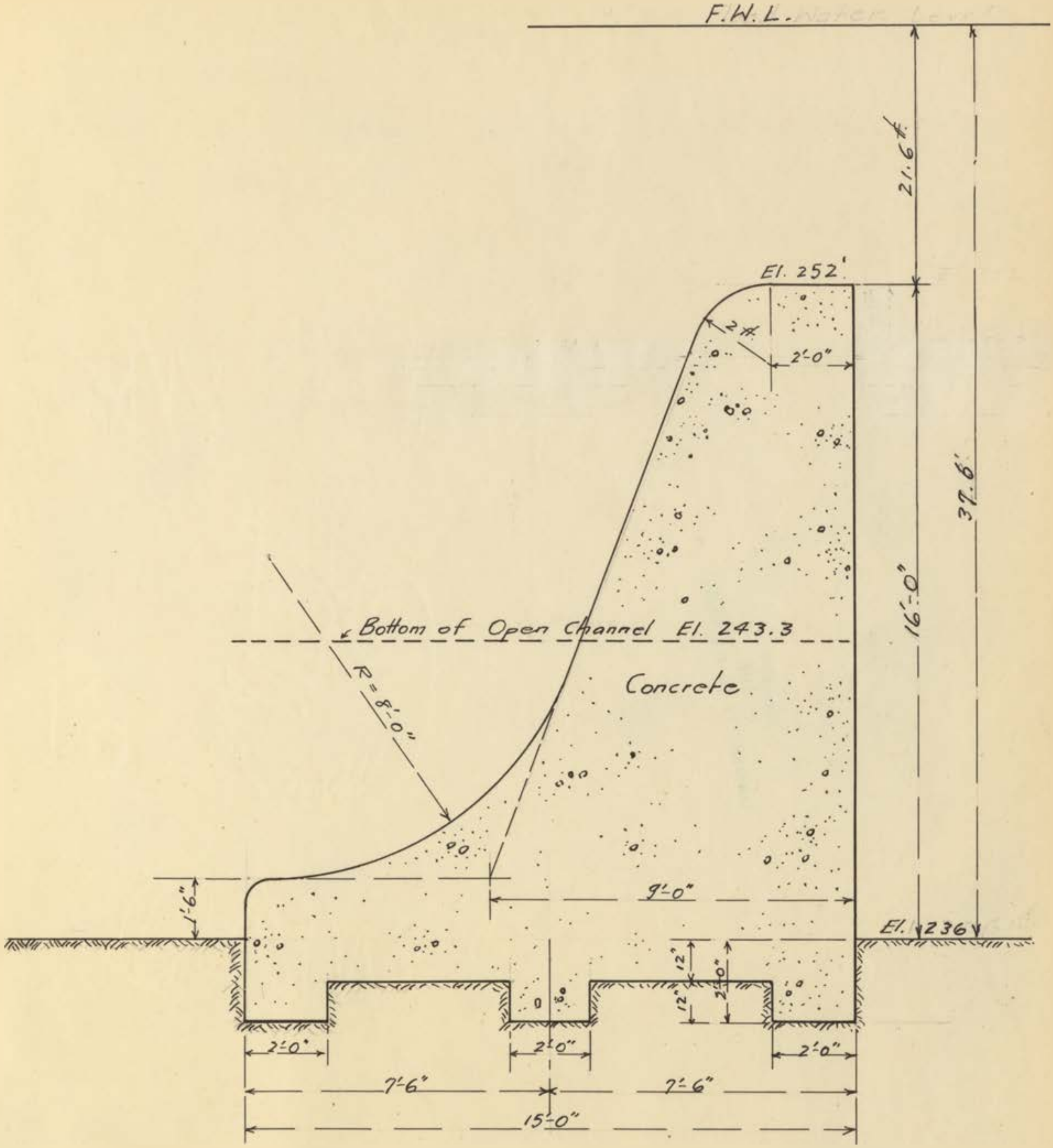
$$X = \frac{21{,}600 \times 5.33}{17{,}800} = 6.46 \text{ feet.}$$

Therefore the distance from the turning point to the point of resultant force acting is 6.46 + 3.49 = 9.95 feet.
therfore the assumption fulfills the requirement of the stability of over turning.

Stability against sliding effect.

The dam is constructed upon the rock foundation which should be prepared as shown on plate no.41 , before concrete is work begun. The horizontal pressure of water tends to slide the dam down streamward, which is assumed to be resisted by the vertical face of the rock pivot.

The area of pivot is assumed to be 3 square feet. Pressure on the face is 21,600/3 and about 3.5 ton per square



Scale 1/4" = 1'-0"

CROSS SECTION OF GRAVITY DAM.

foot, while the allowable crushing strength of lava may be taken as high as 4 tons. Therefore the dam is safe from the sliding.

The resisting strength of the dam at its base against the shearing off tendency is I5 x I x $\overline{I2}^{2}$ x 600 = I,295,000 lbs.

This is far beyond the actual force which might act.

Remark.

Looking to future extension , the hight of dam is I.7 ft. higher than required by the calculations.

PART 8

Power Plant .

Location .

The power plant is located along the river side about I.5 miles from the mouth of the White Salmon River, and close to the public road which runs from Underwood, a station on the Union Pacific R. R., to Husum. In connection with the head and tail race, and selection of the site for the power house, the character of soil is considered and it is found that the proposed site consists of a natural rock.

Building.

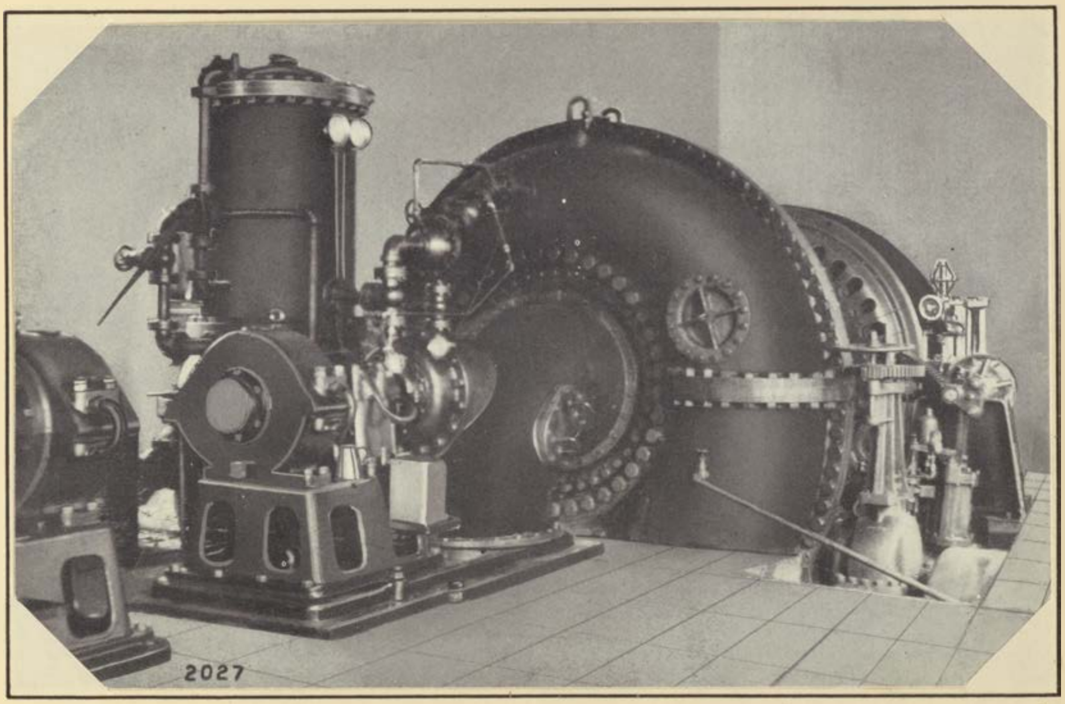
The plant is designed for a capacity 3,000 K.W., and I,000 K.W. additional extension can be taken care of by a little additional expenditure. It is equipped with three New Amercan turbines of horizontal type which are mounted on shafts coupled to the generators and supplied by closed penstocks. Two exciter units are directly connected to the high speed Platt Victor Francis type turbines.

All materials used in the construction of the power plant are fire proof . Roof trusses and columns are steel and the roofing is made of cinder concrete. A 30 tons crane runs through the generating room, which is mounted on the steel girder. Walls are entirely made from brick. Floor is built of concrete having granolithic finish of dark color, to render drips of oil inconspicuous.

Foundations are made of 1 ; 3 ; 6 concrete.

Doors are placed near the transformer room and exciters, through which material is received directly from the rail road car.

The size of windows is large to give abundant light for



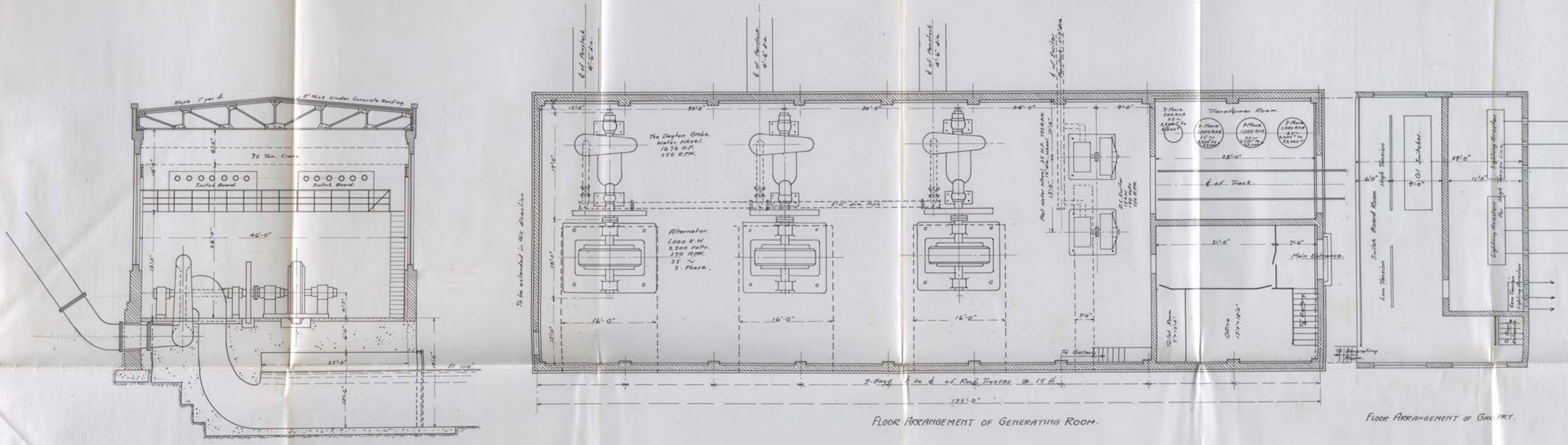
THE ARRANGEMENT OF TURBINE AND GOVERNOR

generating and switching rooms.

To provide for an emergency, in case of a shut down, both generating and switching rooms are provided with a duplicate system of wiring for the lighting.

Plate No.43 shows the general arrangement of the plant , and plate No.15. shows the location of the power plant.

The view of proposed installation of the turbine , governor and generator is shown on plate no.42.



SECTIONAL VIEW.

FLOOR ARRANGEMENT OF GENERATING ROOM.

FLOOR ARRANGEMENT OF GALLERY.

GENERAL ARRANGEMENT OF
THE WHITE SALMON RIVER
POWER PLANT

Scale 1/8"=1'0"

PART 9.

Financial Consideration.

An estimation for the first cost , and annual operating expenses for this development is going to be considered in this part. And from this estimation the minimum cost of power that can be sold to the customers is calculated. These results are tabulated on the following pages.

Cost of building.

2,630 bl.	cement		@	$ 2.00	$ 5,260.
I,II0 bl.	sand		@	.60	666.
2,320 cub. yard	gravel		@	.55	I,276.
2,388 " "	concrete setting		@	.80	I,9I0.
4I0,000	brick	per M.	@	9.00	3,690.
"	" labor	" "	@	6.00	2,460.
6,2I0 sq. ft.	window frame	per sq. ft.	@	.80	I,920.
490 " "	door	" "	@	.20	98.
I7,600 lbs.	steel roof truss	per lbs.	@	.04	704.
7,000 "	steel columns	" "	@	.04	280.
I- 26 step	stair 3 '	per step	@	I.75	39.
I- 26 "	" 4'	" "	@	I.75	45.5
43 ft.	railing (pipe)	per ft.	@	I.00	43.
2I2 ft.	crane runway	per ft.	@	I.60	339.2
46 "	crane girder				320.
30 tons	crane motors				250.
I334 sq. ft.	2 nd. floor flooring,	per ft.	@	.35	466.9
Erection of roof trusses & columns					265.

Total cost of building $ 2I,I50.

Cost of Swtch Board.

			$	$
I	generator pannel			I50.
I5	oil switch	@	60.	900.
I	synchroscope	@	50.	50
3	field dischage switch with rheostat			I8.
I	A.C. ammeter	@	25.	25.
I	A.C. voltmeter	@	25.	25.
3	rheostat for generator field			45.
3	set of apparatus for voltage transformer , current transformer and plugging			90.
3	main generator switches and circuit breakers			I20.
3	feeder pannel			400.
3	A.C. ammeter	@	25.	75.
3	integrating wattmeter	@	60.	I80.
3	A.C. voltmeter	@	25.	75.
3	set of aut. circuit breaker.			I20.
3	set of apparatus for current and volt transformer			90.
I	totalizing pannel			I50.
I	integrating wattmeter (high tension)			40.
I	" " (low tension)			40.
I	frequencymeter			40.
I	main voltmeter (high tension)			25.
I	" " (low tension)			25.
	Necessary current and volt transformer and plug.			90.

I	D.C. pannel	$ 50.
I	D.C. ammeter	I6.
I	D.C. voltmeter	I6.
2	three pole switch	IO.
2	rheostat	30.
2	lightning arrester	200.
I	" "	80.
Bus bars & etc.		505.
Installation and wiring		I,300.
	Total cost of switch board	$ 5,IOO.

Cost of Penstocks.

			$	$
3	70" dia, 50 ft. long, I/4 in. thick.	@	I8.	2,700.
3	54" dia, I00 ft. long, 3/8 in. thick.	@	I5.	4,500.
I	I4" dia, I60 ft. long , 3/I6 in. thick.	@	2.	320.
3	Automatic cup valve for 7o" dia pipe			5,000.
I	" " " for I4" dia. pipe			800.
I set of exhaust pipe				I50.
Valves at station				250.
Piping in station 200 x 2 dia.				400.
Foundation for penstocks' beds				200.
Labor erecting				I,I30.
	Total cost of penstocks			$ I5,450.

Cost of Head gate and Spillway.

I	Gate 6' x 7' per sq. ft.	@	2.	84.
I set of gearing and handle				20.
Racks	I3' x 8' per sq. ft.	@	0.60	62.4
Labor setting				83.6
II0 cub yard	concrete work per cub. yard		5.	550.
	Total cost of head gate and spillway			$ 800.

Cost of Flume Line.

9,200 ft. long per linear ft.	@	I.	9,200
Setting			3,800.
Total cost of flume line			$ I3,000.

Cost of Rock Excavation.

I4,200 Cub. yard per cub. yard (channel and dam)	@	3.	42,600.
5,000 cub. yard per cub. yard (station)	@	3.	I5,000.

Total cost of rock excavation	$ 47,300.

Cost of Dam and Inlet.

400 cub. yard concrete per cub. yard @ 5.	$ 2,000.
Total Cost of Water Conductor	$ 78,550.

Cost of Transmission Line.

Materials:-

2I0 ton Copper line, per ton at $ 320.	$ 67,200.
3I7 Pole for 2-circuit 33,000 V. per set at 20.	6,340.
476 " " 6,600 V. " " 8.	3,803.
I,473 " single circuit 33,000. V. " " I0.	I0,473.
3I7 cross arm 4.5" x 6" x I8' at 2.	634.
476 " " 3"x 6" x I0' at $ I.2	572.
I473 " " 3.25" x 6" x 7' at $ I.	I,473.
I3,ooo Insulator 33,000. V. at 0.55	7,I50.
I3,000 " pin " " 0.35	4,550.
Set of line materials for 6,600 V.	I,36I.
Bolts and brace, etc.	2,500.
80,000 ft. galv.wire for guy at 0.0I4	I,I20.
2 set of section switches and poles	I50.

Labor:-

Distributing poles at $ per mile	4,8I5.
Excavation at $ 67. per mile	7,I69.
Lighting arrester ground at $ 20. per mile	2,I40.
Distributing materials at $ 30. per mile	3,2I0.

COst of Special Towers. (200 ft. navigable clearance)

4 Tower 20 ton per tower at $ 80. per ton	6,400.

Labor for erection of special towers		$ 500.
Total cost of transmission line	$ I3I,550.	

Cost of Plant Complete.

Building	$ 2I,I50.
3- I,000 K.W. generator	36,000.
3 - I,676 H.P. water turbine with governer etc.	30,000.
2 - I5 K.W. exciter	500.
2 - 25 H.P. exciter turbine with regulator	350.
3 - I,000 K.V.A. transformer	24,000.
I - 200 K.V.A. "	I,800.
Switch board	5,I00.
Transmission line	I3I,550.
Water conductor	78,550.
I00 Acres land at $ 80. per acre	8,000.
Engineering and superintendence	I3,000.
Machine installation and wiring	3,000.
3840 K.V.A. Transformers for distribution of load.	30,000.
Total cost of plant complete	$ 383,000.

Operating Expenses per annum .

Station :-	
4 - laborers at $ 2. per day for 360days per year	2,880.
I - man as manager	2,000.
Transmission line	
I0 - line men at $ 720 per year	7,200.
I clerk. per year at I,000	I,000.
Oil and waste	800.
Repair to machinary and building	500.

Incidental expenses		$ 720.
Total operating expenses	$ I4,600.	

Finances.

Average load for 3 months is I,205 K.W. and 28,920 K.W.Hr. per day for three months is 2,602,800 K.W.Hr.

Average load for 9 months I,060 K.W. and for nine months is 6,868,800 K.W.Hr. Total K.W.Hr. per annum (360 days.) would be 9,47I,600 K.W.Hr.

Expenditures:-

Capital required for the development		$ 383,000.
Interest on investment at 6 %		22,980.
Taxes on real estate building etc.		820.
Depreciation on building at I %		260.
" " water wheel at 3 %		900.
" " generators " "		I,080.
" " pole at IO %		5,000.
" " line at 3 %		2,I00.
" " other electrical equip. at 3 %		I00.
" " penstocks at 3 %		460.
" " water conductor at IO % (wooden flume)		I,300.
" " other water conductors at I % (dam & channel)		500.
" " transformer at 3 %		1,650.
Total fixed charge	$ 37,150.	
Operating expenses	I4,600.	
Total cost per annum	$ 47,050.	

$$\text{Min. selling charge per K.W.Hr.} = \frac{5175000}{9471600} = 0.546 \text{ cents}$$

Conclusion.

As seen from the foregoing estimations, and calculations, according to this design, the selling charge of K.W.Hr. would be about 0.55 cent. Therefore this plant would be a profitable undertaking. Farther more as mentioned in foregoing parts the plant may be extended I,000 K.W. unit with a little expenditure with expansion of demand of market. Consequently the investment for this undertaking is considered a financial success.

Bibilography. (Part 2 to 9.)

Note on M & S.E. 9. Prof. M.L.Enger, U.OfI. 1912.

Note on E.E. 14. Prof. E.B.Paine, U.ofI. 1911.

Note on E.E. 17. Prof. E.B.Paine, U.of I. 1912.

Note on E.E. 34. Prof. E.H.Waldo, U.of I. 1912.

Electrical Energy Dr. E.J.Berg, Mc Graw Co. 1908.

Water Power Engineering. D.W.Mead " 1909.

Mill Building Tyrell, Myron C. Clark, 1911.

Element of Electricl Engineering Frankline & Esty V. I
Mc Graw Hill Co. 1909.

Standard Hand-Book for E.E. " " 1908.

Standarization Rules of A.I.E.E. 1911.

Hydro-Electric Power Plant. L. Lydon 1910.

Transmission Calculation Rosenthal 1909.

Hydro-Electric Developments and Engineering. F. Koester
D. VanNostrand Co. 1909.

Mordern Turbine Practice Turso, " " 1907.

Hydrolic Turbine. Gelpke & Van Cleve , Mc Graw Hill Co.
1911.

Hydro-Electric Practice. Von Schon , Lippincott. 1908.

Text Book on Hydraulic. Hoskins , Henry Holt Co. 1908.

Water Supply Paper No. 253 & 272 U.S. Geological Survey,
1911.

Cambria 1909.

Kent's Mechanical Engineer's Pocket Book 1909.

Trautwine's Engineer's Pocket-Book. 1906.

Electrical World . 110,000 volt transmission system of the
province of Ontario. Jan. 6, 1912.

Mechanical Stresses In Transmission Lines A. Guell.
Bulletin No. 54 U. Of I. 1912.

Comments on Fixed Costs in Industrial Power Plants
J. C. Parker A.I.E.E. March 10 , 1911.

Some Problems of High-Voltage Transmissions C. P. Steinmetz
A.I.E.E. March 8, 1912.

Advantages of Unified Electric Systems Covering Large Territories. W. B. Jackson A.I.E.E. Feb. 10, 1911.

Public Water Supply F. E. Turneaure 1908